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REFERENCE MANUAL OF COUNTERMEASURES FOR HAZARDOUS SUBSTANCE RELEASES

by

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Contract No. 68-03-3014

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When a release of hazardous substances has occurred or threatens to occur, federal, state, local government or industrial personnel may have to assume responsibility for immediate and planned removal which is the principal cleanup and treatment phase. They must select treatment and disposal processes, or countermeasures, which are effective for the particular hazardous substances and circumstances of the release.

This manual contains procedures to assist response personnel in selecting optimum countermeasures. The procedures make up a rational methodology which consists of four decision-making steps in series, starting with identification of the substance(s) involved and site-specific parameters, and ending with an optimization of technically feasible countermeasures in the light of economic, logistic, and other criteria. The methodology uses comprehensive tables, or matrices, which provide technical guidance for almost 700 hazardous substances designated by the Comprehensive Environmental Response, Compensation and Liability Act of 1980, otherwise known as CERCLA or Superfund (PL96-510). Remedial action of a long-term nature, which follows removal, is not addressed here.

The manual is designed as a reference for use in field or office and stands alone. It is based on available, sometimes incomplete, sources. Its purpose is to provide persons with a limited background a fast, workable guide to plausible removal countermeasures, given a reasonable amount of knowledge about the release. The user should be cognizant of federal, state and local regulations that may impact the decision to select specific countermeasures, and of the fact that these regulations may be amended from time to time. An example of the application of the manual to a real situation is included.

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This document has been reviewed in accordance with U.S. Environmental Protection Agency Policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report is a reference manual of countermeasures designed to assist responders to spills of hazardous substances. After helping to identify the specific substances involved and the media into which they were released, the manual provides technically and logistically applicable treatment and disposal methods for nearly 700 designated hazardous substances. The manual enables persons with a limited background to select plausible removal countermeasures in a short time without other reference materials.

For further information, please contact the Land Pollution Control Division of the Hazardous Waste Engineering Research Laboratory.

Thomas R. Houser, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

When a release of hazardous substances has occurred or threatens to occur, federal, state, local government or industrial personnel may have to assume responsibility for immediate and planned removal which is the principal cleanup and treatment phase. They must select treatment and disposal processes, or countermeasures, which are effective for the particular hazardous substances and circumstances of the release.

This manual contains procedures to assist response personnel in selecting optimum countermeasures. The procedures make up a rational methodology which consists of four decision-making steps in series, starting with identification of the substances(s) involved and site-specific parameters, and ending with an optimization of technically feasible countermeasures in the light of economic, logistic, and other criteria. The methodology uses comprehensive tables, or matrices, which provide technical guidance for almost 700 hazardous substances designated by the Comprehensive Environmental Response, Compensation and Liability Act of 1980, otherwise known as CERCLA or Superfund (PL96-510). Remedial action of a long-term nature, which follows removal, is not addressed here.

The manual is designed as a reference for use in field or office and stands alone. It is based on available, sometimes incomplete, sources. Its purpose is to provide persons with a limited background a fast, workable guide to plausible removal countermeasures, given a reasonable amount of knowledge about the release. The user should be cognizant of federal, state and local regulations that may impact the decision to select specific countermeasures, and of the fact that these regulations may be amended from time to time. An example of the application of the manual to a real situation is included.

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SECTION 1

INTRODUCTION AND USE OF THE MANUAL

OBJECTIVES AND BACKGROUND

This manual is designed to assist federal, state, and local government and industry personnel who may find it necessary to respond to a release (or threat of a release) of hazardous substances designated in the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Approximately 700 hazardous substances have been designated pursuant to CERCLA Section 101(14). The manual applies to many types of releases, including transportation and non-transportation related ones as well as those from hazardous waste sites.

The manual guides the responder through a series of decisions and actions to be taken at the site of the release or potential release. Actions such as these are mandated by the National Contingency Plan (NCP) (40 CFR Part 300).

Note that regulations may be amended from time to time, as may lists of regulated chemicals. Check to see that your information is up-to-date.

MANUAL CONTENTS

The entire manual is summarized in Figure 1, which shows how Sections 2 to 5 are used in the selection of countermeasures for a given release situation.

Section 2 of the manual provides guidelines for situation assessment. This provides for the identification of the hazardous substance and determination of the proper response procedures dependent on the medium (atmosphere, surface water, ground) receiving the release. Discussions on site assessment, guidelines for protective clothing selection, and equipment decontamination at the affected sites are offered in Appendices A, B, and C.

Section 3 addresses the selection of countermeasures. The information generated in Section 2 is utilized in three steps: The "A" Tables disclose the physical nature of the hazardous substances involved and the associated hazards; the "B" Tables establish various technically feasible countermeasures based on Tables A; and the "C" Tables give the optimal countermeasures in light of applicable criteria and parameters. Note that the number-letter combination identifying each table is based both on the nature of the spilled substance and on the type of receiving medium. The term countermeasure includes physical, chemical, and biological cleanup; treatment; and disposal processes to be carried out on-site or off-site. Countermeasure selection criteria include considerations of the degree of cleanup achievable, environ-

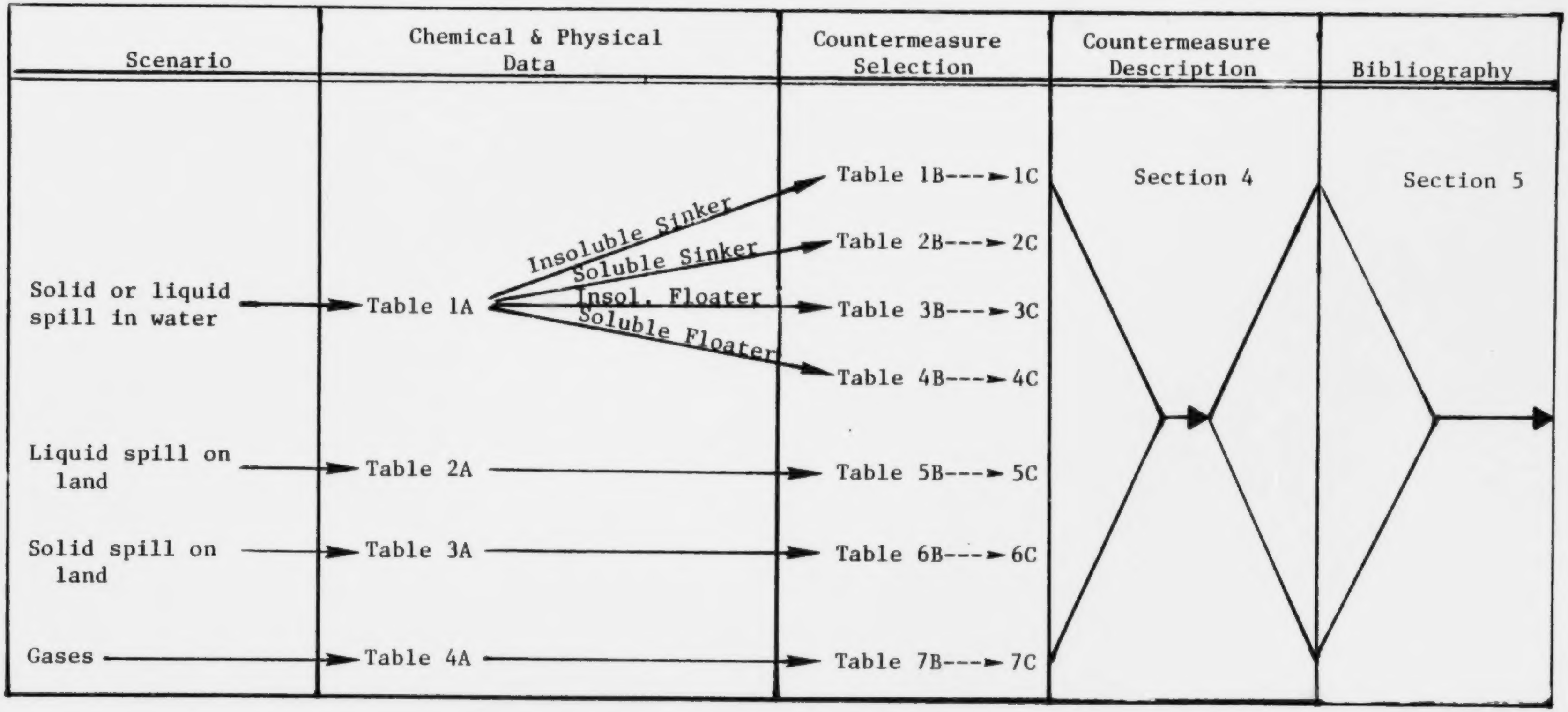
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Figure 1. Pathways in the use of the manual

mental factors, logistics, safety, and cost. One possible alternative is to take no immediate action and rely on isolation alone until such time as the hazards have lessened and suitable countermeasures can be applied.

Section 4 lists all countermeasures described in Section 3. The countermeasures are categorized and defined in terms of their characteristics, advantages, and disadvantages. Having been presented at the conclusion of Section 3 with one or more optimal countermeasures, the responder may make the final choices by referring to this listing. An important use of the listing occurs when a release consists of two or more hazardous substances. It is crucial that synergistic effects be considered. The application of different countermeasures in parallel or in series must then be closely examined.

Section 5 lists the bibliography which underlies the entire manual. A total of 285 sources were accessed; of these, 235 were reviewed and 203 distinct sources extracted. The cut-off publication date for bibliography sources was 1983. The bibliography is categorized with major headings similar to those used in Sections 3 and 4 and arranged alphabetically by author within each category. Section 4 references the original sources so that the responder may obtain more detailed information, if desired. The final subsection, "General Sources," contains a list of references, each of which may address a number of different countermeasures.

Three appendices conclude the manual. All three are devoted to safety aspects necessary in the approach, entry, and decontamination of a hazardous spill or waste site. Appendix A presents suggested guidelines for site assessment, entry, and control. Appendix B provides details on suggested guidelines for selection of chemical resistant clothing. Appendix C discusses decontamination protocols in terms of work zones, safety clothing, and equipment.

USE OF THE MANUAL - BRIEF OVERVIEW

The selection of countermeasures for a given release situation are illustrated in Figure 1 (pg. 2). Briefly, four steps are carried out in series:

1. The Spill Scenario is obtained from Section 2:

    the Hazardous Substance and its state (liquid, solid, gas); and the Medium (water, land, atmosphere) into which it is released.

2. Chemical and Physical Data of the released substance are obtained from the "A" Tables in Section 3:

    Releases in water - Table 1A; Liquids released on land - Table 2A; Particulate solids released on land - Table 3A; Compressed gases released into air - Table 4A.

3. Technically Feasible Countermeasures are obtained from the "B" Tables in Section 3:

Spills on water: insoluble sinkers - Table 1B; soluble sinkers - Table 2B; insoluble floaters - Table 3B; soluble floaters - Table 4B; Liquid spills on land - Table 5B; Particulate solid spills on land - Table 6B; Compressed gases released into air - Table 7B.

4. Optimum Countermeasures are selected from among the Technically Feasible Countermeasures by using the "C" Tables in Section 3 (Tables 1C through 7C correspond to Tables 1B through 7B). For more details about items 1 to 4 above, the manual presents:
   - o Descriptions of the Countermeasures and their characteristics (for better understanding of the Optimum Countermeasures) in Section 4, and a
   - o Listing of the Original Sources from which Descriptions of the Countermeasures were taken (including both specific and general references) in Section 5.

The preceding decision-making methodology has related to one hazardous substance release into one environmental medium. The correlating parameter in steps 2 and 3 is the chemical class to which the substance of interest has been assigned. The countermeasures then depend on the chemical class. Actual spill situations may involve (a) hazardous substance(s) belonging to more than one chemical class and (b) scenarios of more than one hazardous substance being released into more than one environmental medium.

For eventualities (a) and (b), the following procedure is suggested. The responder should carry out steps 2, 3, and 4 for all alternative chemical classes, hazardous substances, and media pertaining to the incident. The result will be a multiplicity of feasible and optimum countermeasures, usually a choice of several for any one set of inputs. The responder should select countermeasures which are common to the chemical classes and substances released into each medium. Also, a judgment must be made about the cleanup priority of each medium, e.g., should countermeasures for different media be performed in series or in parallel, or in some other time relationship? To help the user with such decisions, the material in Sections 4 and 5 emphasizes logistics, speed of deployment, cost of different countermeasures, etc.

COUNTERMEASURE CONSIDERATIONS

The reader is invited to refer to Table 8, which lists all the countermeasures considered in this manual. The many techniques for containment, treatment, and disposal need to be considered from basic, practical aspects. Depending on the location of the treatment and any interference with the environment, three types of countermeasures are possible:

1. In Situ: the spill site is not significantly disturbed by the treatment method carried out on the site, e.g., radio-frequency heating of ground surface using implanted electrodes (removed after treatment) to distill off organic pollutants.

2. On Site: the spill site is disturbed by the treatment method which is carried out on the site, e.g., contaminated soil is excavated, incinerated on the site in mobile incinerators, and the clean soil is replaced on the site.

3. Off Site: the spill site is disturbed, and the contaminated material transported off the site is either (a) treated in a (central) facility [with the clean material either returned back to the site or disposed of in the vicinity of the treatment facility] or (b) disposed of with no or minimal treatment in a proper disposal site.

These three basic categories determine the cost structure (treatment and disposal vs. transportation costs) of the countermeasure, and also the regulatory requirements. The responder should be conversant with or at least aware of the federal, state, and local environmental regulations which may make some countermeasures, otherwise preferred, unsuitable. Typical examples are the need to obtain permits for treatment methods (such as incineration, which could change a solid or liquid pollution problem into an air pollution problem) or transportation of hazardous wastes across certain cities or states. Regulations change with time and location and are not covered in this manual.

EXAMPLE OF MANUAL USE

To illustrate how a responder would use the manual, the following typical spill scenario is given. A train has derailed. Several tank cars carrying various chemicals are off the tracks. One car containing acrylonitrile has ruptured, and the contents are leaking from the car and running into a nearby stream. The stream is slow moving and quite small. It serves neither as a source of domestic water nor as a recreation area. However, it does flow into a major waterway approximately five miles downstream from the spill. The major waterway is a source of both potable water and recreation for a large metropolitan area.

The responders in this situation are actually presented with two spill scenarios: one involving a liquid spill on land and the other a liquid spill in water. Containment procedures, probably different for each situation, must be initiated simultaneously. Once containment of the spilled material has been achieved, displacement, treatment and/or disposal countermeasures can be applied to the contaminated soil and water. Treatment countermeasures need not be conducted simultaneously for each situation. Indeed, the spill of acrylonitrile in the stream presents a much more immediate and serious threat to the environment and nearby populace than does the material spilled on land. The responder, in all likelihood, will concentrate on treating the contaminated stream first and the soil second.

The Countermeasures Manual addresses four specific and individual spill scenarios; and not multi-media events, as given in this example. When confronted with a multi-media spill, the responder must separate it into two (or more) "single media spills"; consult this manual for feasibility countermeasures for each "single media spill"; and then determine the best combination of countermeasures to apply.

Figure 1 (page 2) illustrates the various pathways available to a responder. In the example spill above, responders must address to the land spill and the water spill independently and then make proper use of the manual.

A glance at Figure 1 (page 2) will tell the responder in the example spill that the first step in the use of the manual is to consult Tables 1A and 2A for chemical and physical data on acrylonitrile. From page 14 of the "A" Tables (which begin on page 13) the responder learns that acrylonitrile is included in the Cyanide and Nitrile chemical class, its CAS registry number is 107-13-1; that, in addition to being toxic, it is also considered to be flammable with toxic products, polymerizable, a potential carcinogen, and poisonous. This information will tell the responder what precautions must be considered. The key pieces of information to be gleaned from the "A" Tables, however, are that acrylonitrile is in the Cyanide and Nitrile chemical class and that, in water, it is a soluble floater. Armed with this information, the responder can now proceed to the "B" Tables (which begin on page 92).

The "B" Tables indicate countermeasures which are technically feasible for a given class of chemical. The countermeasures are divided into the containment, displacement, treatment, and disposal categories. Referring again to the spills in the example above, the responder has learned that acrylonitrile is a soluble floater in water (from Table 1A) and must consult Table 4B (page 97) to address the water spill and Table 5B (page 98) to address the land spill. Here the responder will find lists of feasible countermeasures for the Cyanide and Nitrile Class. The responder's primary concern at this point in the water spill scenario is containment of the acrylonitrile and the contaminated water. In this category, four basic containment procedures are listed for soluble floaters spilled on water. These are dikes, berms and dams, surface booms, curtain barriers, and stream diversion. For liquids spilled on land the six containment measures listed are: dikes, berms and dams; trenches; barriers in soil; chemically active covers; synthetic membrane liners; and foam covers. Footnotes to the "B" Tables provide additional information and limitations concerning these countermeasures. The responder is also referred to Section 4 which begins on page 129) for detailed descriptions and information about prospective countermeasures.

From the information contained in Section 4, the "B" Table footnotes, and possibly from the responder's own knowledge and past experiences, certain countermeasures may be eliminated. For those which cannot be eliminated based upon information given thus far, the responder now proceeds to Tables 4C and 5C. These tables contain nontechnical criteria such as logistics, availability, clean-up efficiency and costs. By considering these additional criteria, the responder can now decide which of the technically feasible countermeasures is optimum under the constraints imposed by the particular spill situation.

For our example spill, the responder consults Tables 4C and 5C, and Section 4 for each of the technically feasible countermeasures listed in Tables 4B and 5B for the chemical functional group, Cyanides and Nitriles, and uses the information to select the optimum response.

In the example, the responder decided, based upon costs, availability of equipment and materials, and deployment time, that the optimum cleanup strategy for this spill is as follows. A large trench or pit will be dug and lined with a synthetic material in order to prevent any further contamination of the soil and water, and to contain the acrylonitrile. The material in the pit will be pumped back into a tank car, and any contaminated soil will be excavated and hauled to a secure, permitted landfill. Because the volume of water is not large and is moving slowly, the stream will be dammed above and below the spill to isolate the contaminant. Unpolluted stream water will be diverted around the spill using pumps, while the contaminated water is contained in a pond formed between the dams. Any acrylonitrile floating on the surface will be pumped into a vacuum truck. The contaminated ponded water will be pumped into a portable catch basin for treatment with a precipitating agent; after allowing adequate time for the sediment to settle, the clarified water will be pumped through activated carbon and then discharged below the dam. Once the pond has been pumped dry, any contaminated bottom sediment will be excavated and hauled to a secure, permitted landfill for disposal.

The above example is one illustration of how the methodology in this manual (as depicted in Figure 1) may be used by a responder to select the optimum combinations of countermeasures for a hazardous substance release. The more information is available on the release and its immediate environment, the more effective the selected countermeasures are likely to be.

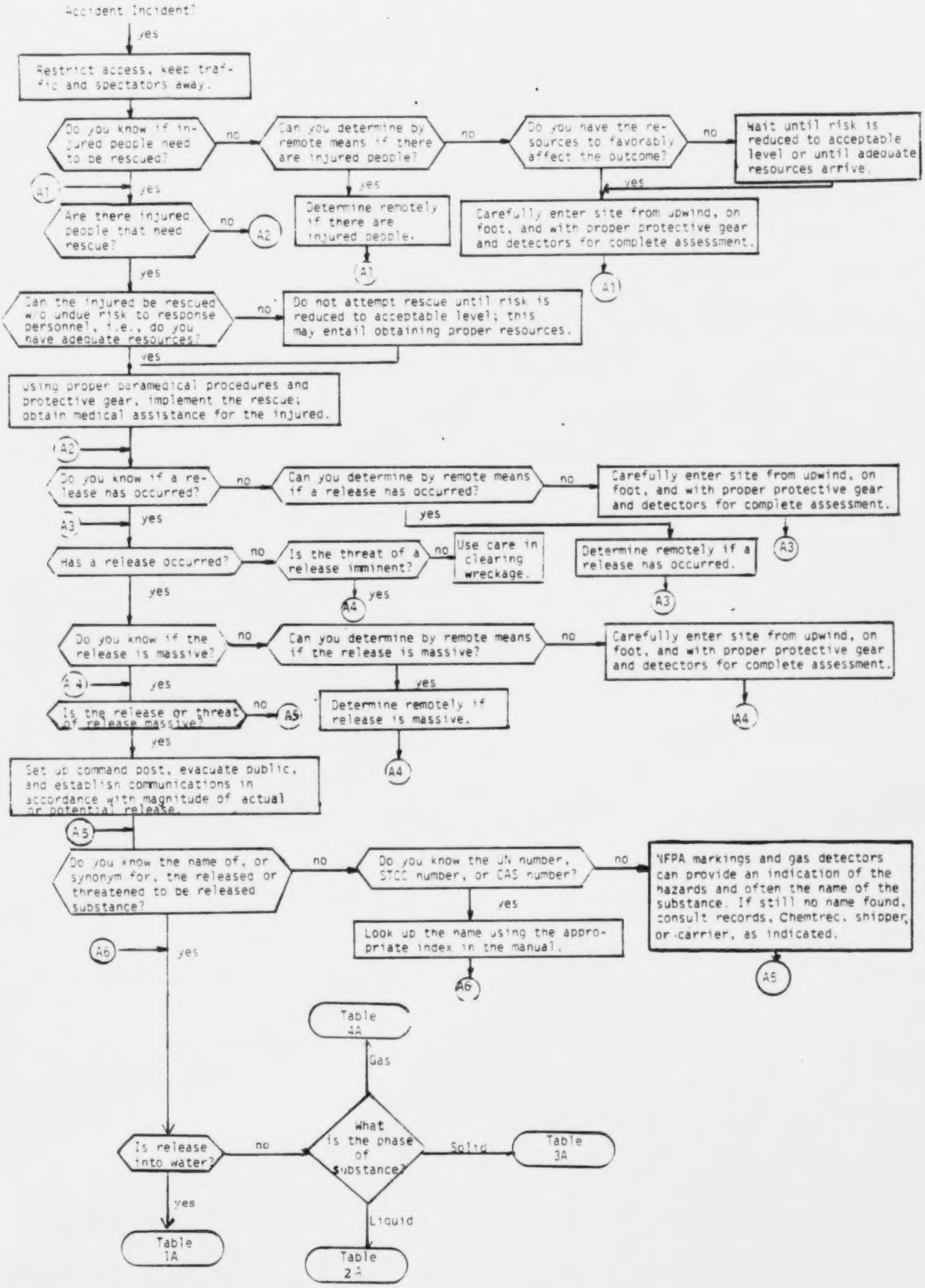
Accident/Incident?
yes
Restrict access, keep traffic and spectators away.
Do you know if injured people need to be rescued?
no
Can you determine by remote means if there are injured people?
no
Do you have the resources to favorably affect the outcome?
no
Wait until risk is reduced to acceptable level or until adequate resources arrive.
yes
yes
Determine remotely if there are injured people.
A1
Carefully enter site from upwind, on foot, and with proper protective gear and detectors for complete assessment.
A1
A1
yes
Are there injured people that need rescue?
no
A2
yes
Can the injured be rescued w/o undue risk to response personnel, i.e., do you have adequate resources?
no
Do not attempt rescue until risk is reduced to acceptable level; this may entail obtaining proper resources.
yes
Using proper paramedical procedures and protective gear, implement the rescue; obtain medical assistance for the injured.
A2
Do you know if a release has occurred?
no
Can you determine by remote means if a release has occurred?
no
Carefully enter site from upwind, on foot, and with proper protective gear and detectors for complete assessment.
yes
A3
A3
yes
Has a release occurred?
no
Is the threat of a release imminent?
no
Use care in clearing wreckage.
Determine remotely if a release has occurred.
yes
A4
A3
yes
Do you know if the release is massive?
no
Can you determine by remote means if the release is massive?
no
Carefully enter site from upwind, on foot, and with proper protective gear and detectors for complete assessment.
A4
yes
yes
Is the release or threat of release massive?
no
A5
Determine remotely if release is massive.
A4
A4
yes
Set up command post, evacuate public, and establish communications in accordance with magnitude of actual or potential release.
A5
Do you know the name of, or synonym for, the released or threatened to be released substance?
no
Do you know the UN number, STCC number, or CAS number?
no
NFPA markings and gas detectors can provide an indication of the hazards and often the name of the substance. If still no name found, consult records, Chemtrec, shipper, or carrier, as indicated.
yes
Look up the name using the appropriate index in the manual.
A6
yes
A6
A5
Table 4A
Gas
Is release into water?
no
What is the phase of substance?
Solid
Table 3A
yes
Liquid
Table 1A
Table 2A

Figure 2. Situation Assessment Flowchart

- Injured people as result of incident/exposure
- Fire or threat of fire
- Name, UN, STCC, or CAS number of substance released or markings on tank car, truck or vessel
- Physical state of released substance
    - Solid (vapors present?)
    - Liquid(vapors present?)
    - Gas
- Source of release - (i.e., tank, truck, railcar, fixed facility)
- Approximate volume of release and/or total volume at source
- Media into which release has occurred and anticipated movement of spill
- Local terrain/accessibility
    - Topography
    - Porosity of ground surface
    - Distance to drinking water supplies
    - Distance to population centers and public areas such as schools, churches, public buildings, busy intersections, shopping centers, recreational facilities
    - Distance to sewers and watercourses
    - Distance from other hazardous substances
    - Distance to food and feed processing facilities
- Weather conditions currently at site or forecast over next 24 hours
    - Wind speed and direction
    - Air/ground/water temperature, as applicable
    - Precipitation

Figure 3. Site Assessment Checklist

SECTION 2

SITUATION ASSESSMENT

From the start, it is assumed that an incident or accident took place, possibly involving a hazardous substance. The responder's first step is to find out if a hazardous substance really was involved, and if so, whether a release occurred or is threatening to occur. The sequence of steps to be taken in assessing the situation and deciding what actions to take is shown in the Situation Assessment Flowchart (Figure 2). Early on, the responder must make observations of the specific site (either remotely, or by entering the site, or both) in order to obtain essential data on the release incident. These data are shown on the Site Assessment Checklist (Figure 3).

The responder should follow through the Flowchart from top to bottom carrying out action items (in rectangular boxes) as necessary in order to obtain sufficient information to complete the Checklist. This checklist will be needed as input to both the "A" tables and the "C" tables in Section 3.

The output at the bottom of the flowchart will establish the substance (or substances) released, its form (solid, liquid, gas), and the medium into which it is released (water, ground, atmosphere). These guide the responder to the proper "A" Table in Section 3.

Proper safety precautions are paramount in site assessment activities, especially when entering a site containing unknown hazards. The site must be monitored and necessary measurements made to establish the presence and concentrations of any hazardous substances. Contaminants from the site must also be controlled to prevent exposure of personnel and the general public. All these actions are described in Appendix A, Guidelines for Site Assessment, Entry and Control which the responder should consult when on-site observations must be made. Appendix B, Suggested Guidelines for Selecting Chemical Protective Clothing, and Appendix C, Personnel and Response Equipment Decontamination should also be consulted, since they contain additional information on personnel protective clothing and decontamination protocols, respectively.

As shown in the Situation Assessment Flowchart (Figure 2), essential data on the release incident may be obtained from CHEMTREC, the Chemical Transportation Emergency Center. CHEMTREC provides information and/or assistance to those involved in, or responding to, hazardous substance emergencies through its 24 hours a day, seven days a week, toll-free Chemical Emergency Telephone Number: 800-424-9300. While the Center's primary mission is to help in transportation incidents, it also provides support in non-transportation situations involving hazardous substance emergencies. In addition, the DOT 1984 Emergency Response Guidebook for Hazardous Materials Incidents (DOT P 5800.3) provides useful information for identification of hazardous substances. Placards containing a four-digit ID number are required on all commercial transports carrying hazardous materials as regulated by the DOT. A responder can identify the common shipping name of a hazardous substance via the four-digit ID number by using the DOT Guidebook. In many cases the common shipping name is the CERCLA hazardous substance name used in the "A" Tables within this countermeasures manual.

SECTION 3

SELECTION OF COUNTERMEASURES

From Section 2 the responder will have determined the name of each hazardous substance (if more than one are present) and the medium or media impacted. The "A" Tables in this section should then be consulted to find out the substance's chemical class, its hazards (in addition to toxicity), and, in the case of a release into water, the physical behavior of the substance on release (float/sink, soluble/insoluble). For a release on water, Tables 1A should be scanned; for a release on land, Tables 2A and 3A; and for an air release, Table 4A. The CAS (Chemical Abstract Service) number for each substance is also included in the "A" Tables for identifying substances known by more than one name.

Just as there are seven classes of post-release behavior, there are seven "B" Tables (1B through 7B), one for each such class. In the "B" Tables check marks indicate countermeasures which are technically feasible for the various chemical classes. The responder can thus find, in general, several countermeasures which could be used for each hazardous substance.

It remains now to select the optimum countermeasures by applying non-technical criteria, such as logistics, availability, efficiency, and cost. Seven "C" Tables (1C through 7C), again one for each of the classes of post-release physical behavior, are provided. The "C" Tables list numerical or descriptive values for each of the selection criteria (e.g. deployment time, cost dollars, cleanup efficiency, etc.) as they apply to each countermeasure. Now one should again refer to the Site Assessment Checklist which resulted from the Situation Assessment (Section 2). The responder can now select the specific countermeasures which are optimum for the constraints imposed by the particular release situation, as expressed in the Site Assessment Checklist.

Further refinement of countermeasure selection is available through use of Section 4 in which countermeasures (mechanical containment and displacement; physical, chemical, and biological treatment; and ultimate disposal/destruction) are listed, together with detailed distinguishing characteristics.

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Acenaphthene	Aromatics CAS 83-32-9	Combustible	1B	Insoluble Sinker
Acenaphthylene	Aromatics CAS 208-96-8	Combustible	3B	Insoluble Floater
Acetaldehyde	Aldehydes CAS 75-07-0	Flammable Polymerizable	4B	Soluble
Acetic acid	Acidic compounds, organic CAS 64-19-7	Combustible Corrosive	2B	Soluble
Acetic anhydride	Acidic compounds, organic CAS 108-24-7	Combustible Corrosive	2B	Soluble, decomposes
Acetone	Ketones CAS 67-64-1	Flammable	4B	Soluble
Acetone cyano-hydrin	Cyanides and nitriles CAS 75-86-5	Combustible w/toxic products Poison	4B	Soluble
Acetonitrile	Cyanides and nitriles CAS 75-05-8	Flammable w/toxic products	4B	Soluble
Acetophenone	Ketones CAS 98-86-2	Combustible	1B	Insoluble Sinker
Acetyl bromide	Aliphatics, halogenated CAS 506-96-7	Flammable w/toxic products Corrosive Reactive	2B	Decomposes (Sinker)
Acetyl chloride	Aliphatics, halogenated CAS 75-36-5	Flammable w/toxic products Corrosive Reactive	2B	Decomposes (Sinker)
2-Acetylamino fluorene	Amines, aryl CAS 53-96-3	Potential carcinogen	1B	Insoluble Sinker
1-Acetyl-2-thiourea	Ureas CAS 591-0802		2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Acrolein	Aldehydes Olefins CAS 107-02-8	Flammable Polymerizable Poison	B	Soluble
Acrylamide	Amides, anilides, and imides CAS 79-06-1	Polymerizable	2B	Soluble
Acrylic acid	Acidic compounds, organic Olefins CAS 79-10-7	Combustible Corrosive Polymerizable	2B	Soluble
Acrylonitrile	Cyanides and nitriles CAS 107-13-1	Flammable w/toxic products Polymerizable Potential carcinogen Poison	4B	Soluble
Adipic acid	Acidic compounds, organic CAS 124-04-9		2B	Soluble
Aldicarb	Esters CAS 116-06-3		1B	Insoluble Sinker
Aldrin	Aromatics, halogenated CAS 309-00-2	Combustible w/toxic products Potential carcinogen Poison	1B	Insoluble Sinker
Allyl alcohol	Alcohols & glycols Olefins CAS 107-18-6	Flammable Poison	4B	Soluble
Allyl chloride	Halides, alkyl Olefins CAS 107-05-1	Flammable w/toxic products	3B	Insoluble Floater
Aluminum phosphide	Phosphorous and compounds CAS 20859-73-8	Flammable w/toxic products Reactive	2B	Liberates poisonous phosphine on contact
Aluminum sulfate	Sulfates CAS 10043-01-3		2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
5-(Aminomethyl)-3-isoxazole (Note 1)	Amines, alkyl CAS 2763-96-4		2B	Soluble
Amitrole (Note 1)	Azo compounds CAS 61-82-5	Potential carcinogen	2B	Soluble
Ammonium acetate	Organic ammonium compounds CAS 631-61-8		2B	Soluble
Ammonium benzoate	Organic ammonium compounds CAS 1863-63-4	Combustible w/toxic products	2B	Soluble
Ammonium bicarbonate	Organic ammonium compounds CAS 1066-33-7		2B	Soluble
Ammonium bichromate	Chromates CAS 7789-09-5	Corrosive Oxidizer Flammable	2B	Soluble
Ammonium bifluoride	Halides, inorganic CAS 1341-49-7	Corrosive	2B	Soluble
Ammonium bisulfite	Sulfites CAS 10192-30-0		2B	Soluble
Ammonium carbamate	Esters CAS 1111-78-0		2B	Soluble
Ammonium carbonate	Organic ammonium compounds CAS 10361-29-2		2B	Soluble
Ammonium chloride	Halides, inorganic CAS 12125-02-9		2B	Soluble
Ammonium chromate	Chromates CAS 7788-98-9		2B	Soluble
Ammonium citrate, dibasic	Organic ammonium compounds CAS 3012-65-5		2B	Soluble
Ammonium fluoborate	Organic ammonium compounds CAS 13826-83-0	Corrosive	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Ammonium fluoride	Halides, inorganic CAS 12125-01-8	Corrosive	2B	Soluble
Ammonium hydroxide	Basic compounds CAS 1336-21-6	Corrosive	4B	Soluble
Ammonium oxalate	Organic ammonium compounds CAS 5972-73-6 CAS 14258-49-2 CAS 6009-70-7		2B	Soluble
Ammonium picrate	Nitro compounds CAS 131-74-8	Flammable w/toxic products Explosive	2B	Soluble
Ammonium silicofluoride	Halides, inorganic CAS 16919-19-0	Corrosive	2B	Soluble
Ammonium sulfamate	Sulfones, sulfoxides, & sulfonates CAS 7773-06-0		2B	Soluble
Ammonium sulfide	Sulfides and mercaptans CAS 12135-76-1	Flammable w/toxic products	2B	Soluble
Ammonium sulfite	Sulfites CAS 10196-04-0	Combustible w/toxic products	2B	Soluble
Ammonium tartrate	Organic ammonium compounds CAS 3164-29-2 CAS 14307-43-8		2B	Soluble
Ammonium thiocyanate	Cyanates CAS 1762-95-4	Combustible w/toxic products	2B	Soluble
Ammonium thiosulfate	Sulfates CAS 7783-18-8		2B	Soluble
Ammonium vanadate	Heavy metals CAS 7803-55-6		1B	Insoluble Sinker
Amyl acetate	Esters CAS 628-63-7	Flammable	3B	Insoluble Floater

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Aniline	Amines, aryl CAS 62-53-3	Combustible w/toxic products Poison	2B	Soluble
Anthracene	Aromatics CAS 120-12-7	Combustible	1B	Insoluble Sinker
Antimony	Heavy metals CAS 7440-36-0	Combustible w/toxic products	1B	Insoluble Sinker
Antimony pentachloride	Halides, inorganic Heavy metals CAS 7647-18-9	Corrosive Reactive	2B	Reacts vigorously, liberating HCl
Antimony potassium tartrate	Organometallics Heavy metals CAS 28300-74-5		1B	Insoluble Sinker
Antimony tribromide	Halides, inorganic Heavy metals CAS 7789-61-9	Corrosive Reactive	1B	Insoluble Sinker
Antimony trichloride	Halides, inorganic Heavy metals CAS 10025-91-9	Corrosive Reactive	1B	Reacts vigorously, liberating HCl
Antimony trifluoride	Halides, inorganic Heavy metals CAS 7783-56-4	Corrosive Reactive	2B	Soluble
Antimony trioxide	Oxides Heavy metals CAS 1309-64-4		1B	Insoluble Sinker
Arsenic	Heavy metals CAS 7440-38-2	Combustible w/toxic products Potential carcinogen Poison	1B	Insoluble Sinker
Arsenic acid	Acidic compounds, inorganic Heavy metals CAS 7778-39-4 CAS 1327-52-2	Corrosive Poison	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Arsenic disulfide	Sulfides and mercaptans Heavy metals CAS 1303-32-8	Combustible w/toxic products Poison	1B	Insoluble Sinker
Arsenic pentoxide	Oxides Heavy metals CAS 1303-28-2	Corrosive Poison	2B	Soluble
Arsenic trichloride	Halides, inorganic Heavy metals CAS 7784-34-1	Corrosive Reactive Poison	2B	Decomposes (Sinker)
Arsenic trioxide	Oxides Heavy metals CAS 1327-53-3	Corrosive Poison	2B	Soluble
Arsenic trisulfide	Sulfides and mercaptans Heavy metals CAS 1303-33-9	Combustible w/toxic products Poison	1B	Insoluble Sinker
Asbestos	(See asbestos) CAS 1332-21-4	Potential carcinogen	1B	Insoluble Sinker
Auramine	Amines, aryl CAS 492-80-8	Potential carcinogen	1B	Insoluble Sinker
Azaserine (Note 1)	Azo compounds CAS 115-02-6	Potential carcinogen	2B	Soluble
Barium cyanide	Cyanides and nitriles CAS 542-62-1	Poison	2B	Soluble
3,4-Benzacridine	Aromatics CAS 225-51-4		1B	Insoluble Sinker
Benzal chloride	Aromatics, halogenated CAS 98-87-3		1B	Insoluble Sinker
1,2-Benzanthracene (Note 1)	Aromatics CAS 56-55-3	Potential carcinogen	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Benzene	Aromatics CAS 71-43-2	Flammable Potential carcinogen	3B	Insoluble Floater
Benzenesulfonyl chloride	Acidic compounds, organic CAS 98-09-9	Combustible w/toxic products	1B	Insoluble Sinker
Benzidine	Amines, aryl CAS 92-87-5	Combustible w/toxic products Potential carcinogen Poison	1B	Insoluble Sinker
Benzo[k]fluoranthene	Aromatics CAS 207-08-9	Potential carcinogen	1B	Insoluble Sinker
Benzo[b]fluoranthene	Aromatics CAS 205-99-2	Potential carcinogen	1B	Insoluble Sinker
Benzoic acid	Acidic compounds, organic CAS 65-85-0	Combustible	1B	Insoluble Sinker
Benzonitrile	Cyanides and nitriles CAS 100-47-0	Combustible w/toxic products	2B	Soluble
Benzo[ghi]perylene	Aromatics CAS 191-24-2		1B	Insoluble Sinker
Benzo[a]pyrene	Aromatics CAS 50-32-8	Potential carcinogen	1B	Insoluble Sinker
p-Benzoquinone	Ketones CAS 106-51-4	Combustible	2B	Soluble
Benzotrichloride	Aromatics, halogenated CAS 98-07-7	Combustible w/toxic products Corrosive	2B	Decomposes (Sinker)
Benzoyl chloride	Aromatics, halogenated CAS 98-88-4	Combustible w/toxic products Corrosive	2B	Decomposes (Sinker)
Benzyl chloride	Aromatics, halogenated CAS 100-44-7	Combustible w/toxic products Corrosive Reactive	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Beryllium	Heavy metals CAS 7440-41-7	Flammable w/toxic products Potential carcinogen	1B	Insoluble Sinker
Beryllium chloride	Halides, inorganic Heavy metals CAS 7787-47-5	Poison	2B	Soluble
Beryllium fluoride	Halides, inorganic Heavy metals CAS 7787-49-7	Poison	2B	Soluble
Beryllium nitrate	Nitrates & nitrites Heavy metals CAS 7787-55-5 CAS 13597-99-4	Oxidizer	2B	Soluble
alpha-Benzenehexachloride	Aliphatics, halogenated CAS 319-84-6	Potential carcinogen	1B	Insoluble Sinker
beta-Benzenehexachloride	Aliphatics, halogenated CAS 319-85-7	Potential carcinogen	1B	Insoluble Sinker
delta- Benzenehexachloride	Aliphatics, halogenated CAS 319-86-8	Potential carcinogen	1B	Insoluble Sinker
2,2'-Bioxirane	Epoxides CAS 1464-53-5	Potential carcinogen	2B	Decomposes (Sinker)
Bis(2-chloroethoxy)-methane	Aliphatics, halogenated CAS 111-91-1		2B	Soluble
Bis(2-chloroethyl) ether	Ethers CAS 111-44-4	Combustible w/toxic products Poison	2B	Soluble
Bis(2-chloroisopropyl)-ether	Ethers Aliphatics, halogenated CAS 108-60-1	Combustible w/toxic products	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Bis(chloromethyl) ether	Ethers CAS 542-88-1	Combustible w/toxic products Potential carcinogen	2B	Soluble
Bis(2-ethylhexyl) phthalate	Esters CAS 117-81-7		3B	Insoluble Floater
Bromoacetone (Note 2)	Ketones CAS 598-31-2	Poison	2B	Soluble
Bromoform	Halides, alkyl CAS 75-25-2		1B	Insoluble Sinker
4-Bromophenyl phenyl ether	Ethers Aromatics, halogenated CAS 101-55-3	Combustible w/toxic products	1B	Insoluble Sinker
Brucine	(See strychnine and salts) CAS 357-57-3	Combustible w/toxic products Poison	1B	Insoluble Sinker
1-Butanol	Alcohols & glycols CAS 71-36-3	Flammable	4B	Soluble
2-Butanone peroxide (Note 2)	Peroxides CAS 1338-23-4	Explosive Oxidizer Combustible	2B	Soluble
Butyl acetate	Esters CAS 123-86-4	Flammable	4B	Soluble
Butyl benzyl phthalate	Esters CAS 85-68-7		1B	Insoluble Sinker
Butylamine	Amines, alkyl CAS 109-73-9	Flammable w/toxic products	4B	Soluble
Butyric acid	Acidic compounds, organic CAS 107-92-6	Combustible	4B	Soluble
Cacodylic acid	Organometallics Heavy metals CAS 75-60-5	Poison	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Cadmium	Heavy metals CAS 7440-43-9	Flammable w/toxic products Potential carcinogen	1B	Insoluble Sinker
Cadmium acetate	Organometallics Heavy metals CAS 543-90-8	Poison	2B	Soluble
Cadmium bromide	Halides, inorganic Heavy metals CAS 7789-42-6	Poison	2B	Soluble
Cadmium chloride	Halides, inorganic Heavy metals CAS 10108-64-2	Potential carcinogen	2B	Soluble
Calcium arsenate	Heavy metals CAS 7778-44-1	Poison	1B	Insoluble Sinker
Calcium arsenite	Heavy metals CAS 52740-16-6	Poison	1B	Insoluble Sinker
Calcium carbide	Organometallics CAS 75-20-7	Flammable Reactive	2B	Inflames on contact
Calcium chromate	Chromates CAS 13765-19-0	Potential carcinogen	1B	Insoluble Sinker
Calcium cyanide	Cyanides & nitriles CAS 592-01-8	Reactive Poison	2B	Forms toxic cyanide
Calcium dodecylbenzene sulfonate	Sulfones, sulfoxides & sulfonates CAS 26264-06-2		1B	Insoluble Sinker
Calcium hypochlorite	Halides, inorganic CAS 7778-54-3	Oxidizer	1B	Insoluble Sinker
Captan	Acidic compounds, organic Amides, anilides, and imides CAS 133-06-2	Combustible w/toxic products	1B	Insoluble Sinker
Carbaryl	Esters CAS 63-25-2	Combustible w/toxic products	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Carbofuran	Esters CAS 1563-66-2	Combustible w/toxic products Poison	1B	Insoluble Sinker
Carbon disulfide	Sulfides and mercaptans CAS 75-15-0	Flammable w/toxic products	1B	Insoluble Sinker
Carbon tetrachloride	Halides, alkyl CAS 56-23-5	Potential carcinogen	1B	Insoluble Sinker
Chloral	Aldehydes Aliphatics, halogenated CAS 75-87-6	Combustible w/toxic products Corrosive Potential carcinogen	2B	Soluble
Chlorambucil	Aromatics, halogenated Amines, aryl CAS 305-03-3	Potential carcinogen	1B	Insoluble Sinker
p-Chloro-m-cresol	Phenols & cresols Aromatics, halogenated CAS 59-50-7	Combustible w/toxic products	1B	Insoluble Sinker
Chlordane	Aliphatics, halogenated CAS 57-74-9	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
Chlornaphazine (Note 1)	Amines, aryl CAS 494-03-1	Potential carcinogen	1B	Insoluble Sinker
Chloroacetaldehyde	Aldehydes Aliphatics, halogenated CAS 107-20-0	Combustible w/toxic products Polymerizable	2B	Soluble
p-Chloroaniline	Aromatics, halogenated Amines, aryl CAS 106-47-8		2B	Soluble
Chlorobenzene	Aromatics, halogenated CAS 108-90-7	Flammable w/toxic products	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Chlorodibromomethane	Aliphatics, halogenated CAS 124-48-1		1B	Insoluble Sinker
Chloroethane	Aliphatics, halogenated CAS 75-00-3	Flammable w/toxic products	3B	Insoluble Floater
2-Chloroethyl vinyl ether	Ethers Aliphatics, halogenated CAS 110-75-8	Flammable w/toxic products	2B	Soluble
Chloroform	Halides, alkyl CAS 67-66-3	Potential carcinogen	1B	Insoluble Sinker
Chloromethyl methyl ether	Ethers Aliphatics, halogenated CAS 107-30-2	Flammable w/toxic products Potential carcinogen Poison	1B	Insoluble Sinker
2-Chloronaphthalene	Aromatics, halogenated CAS 91-58-7	Combustible w/toxic products	1B	Insoluble Sinker
2-Chlorophenol	Aromatics, halogenated Phenols & cresols CAS 95-57-8	Combustible w/toxic products	2B	Soluble
4-Chlorophenyl phenyl ether	Ethers, Aromatics, halogenated CAS 7005-72-3	Combustible w/toxic products	1B	Insoluble Sinker
3-Chloropropionitrile	Cyanides & nitriles CAS 542-76-7	Combustible w/toxic products	2B	Soluble
Chlorosulfonic acid	Acidic compounds, organic CAS 7790-94-5	Corrosive Reactive	2B	Dangerously reacts giving off HCl and H_2SO_4
4-Chloro-o-toluidine, hydrochloride	Aromatics, halogenated Amines, aryl CAS 3165-93-3	Poison	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Chlorpyrifos	Organophosphates Aromatics, halogenated CAS 2921-88-2	Combustible w/toxic products	1B	Insoluble Sinker
Chromic acetate	Organometallics CAS 1066-30-4		2B	Soluble
Chromic acid	Acidic compounds, inorganic CAS 11115-74-5	Corrosive Oxidizer Potential carcinogen	2B	Soluble
Chromic sulfate	Sulfates CAS 10101-53-8		2B	Soluble
Chromium	Heavy metals CAS 7440-47-3	Flammable w/toxic products	1B	Insoluble Sinker
Chromous chloride	Halides, inorganic CAS 10049-05-5	Reactive	2B	Soluble
Chrysene	Aromatics CAS 218-01-9	Combustible	1B	Insoluble Sinker
Cobaltous bromide	Halides, inorganic Heavy metals CAS 7789-43-7		2B	Soluble
Cobaltous formate	Organometallics Heavy metals CAS 544-18-3		2B	Soluble
Cobaltous sulfamate	Heavy metals CAS 14017-41-5		1B	Insoluble Sinker
Copper	Heavy metals CAS 7440-50-8		1B	Insoluble Sinker
Copper (cuprous) cyanide	Cyanides & nitriles Heavy metals CAS 544-92-3	Poison	1B	Insoluble Sinker
Coumphos	Organophosphates Aromatics, halogenated CAS 56-72-4	Combustible w/toxic products Poison	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Creosote	Phenols & cresols CAS 8001-58-9	Combustible Potential carcinogen	1B	Insoluble Sinker
Cresol	Phenols & cresols CAS 1319-77-3	Combustible	2B	Soluble
Crotonaldehyde	Aldehydes, Olefins CAS 4170-30-3 CAS 123-73-9	Flammable	4B	Soluble
Cumene	Aromatics CAS 98-82-8	Combustible	3B	Insoluble Floater
Cupric acetate	Organometallics Heavy metals CAS 142-71-2		2B	Soluble
Cupric acetoarsenite	Organometallics Heavy metals CAS 12002-03-8	Poison	1B	Insoluble Sinker
Cupric chloride	Halides, inorganic Heavy metals CAS 7447-39-4		2B	Soluble
Cupric nitrate	Nitrates & nitrites Heavy metals CAS 3251-23-8		2B	Soluble
Cupric oxalate	Organometallics Heavy metals CAS 814-91-5		1B	Insoluble Sinker
Cupric sulfate	Sulfates Heavy metals CAS 7758-98-7		2B	Soluble
Cupric sulfate ammoniated	Sulfates Heavy metals CAS 10380-29-7		2B	Soluble
Cupric tartrate	Organometallics Heavy metals CAS 815-82-7		1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Cyanides (soluble salts and complexes)	Cyanides & nitriles CAS 57-12-5	Poison	2B	Soluble
Cyanogen bromide	Cyanides & nitriles CAS 506-68-3	Poison	2B	Soluble
Cyanogen chloride	Cyanides & nitriles CAS 506-77-4	Poison	2B	Reacts to give toxic cyanide ion
Cyclohexane	Aliphatics CAS 110-82-7	Flammable	3B	Insoluble Floater
Cyclohexanone	Ketones CAS 108-94-1	Combustible	4B	Soluble
Cyclophosphamide (Note 2)	Organophosphates, Amides, anilides, and imides CAS 50-18-0	Potential carcinogen	2B	Soluble
2,4-D acid	Acids, organic Aromatics, halogenated CAS 94-75-7	Combustible w/toxic products	1B	Insoluble Sinker
2,4-D esters	Esters CAS 94-11-1	Combustible w/toxic products	1B	Insoluble Sinker
Daunomycin (Note 1)	Aromatics Ketones CAS 20830-81-3	Potential carcinogen	2B	Soluble
DDD	Aromatics, halogenated CAS 72-54-8	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
DDE	Aromatics, halogenated CAS 72-55-9	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
DDT	Aromatics, halogenated CAS 50-29-3	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
Diallate	Esters CAS 2303-16-4		1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Diazinon	Organophosphates CAS 333-41-5	Combustible w/toxic products	1B	Insoluble Sinker
Dibenzo[a,h]anthracene	Aromatics CAS 53-70-3	Potential carcinogen	1B	Insoluble Sinker
Dibenz[a,i]pyrene	Aromatics CAS 189-55-9	Potential carcinogen	1B	Insoluble Sinker
1,2-Dibromo-3-chloropropane (Note 2)	Aliphatics, halogenated CAS 96-12-8	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
Di-n-butylphthalate	Esters CAS 84-74-2		1B	Insoluble Sinker
Dicamba	Acidic compounds, organic Aromatics, halogenated CAS 1918-00-9	Combustible w/toxic products	1B	Insoluble Sinker
Dichlobenil	Cyanides & nitriles Aromatics, halogenated CAS 1194-65-6	Combustible w/toxic products	1B	Insoluble Sinker
Dichlone	Aromatics, halogenated CAS 117-80-6	Combustible w/toxic products	1B	Insoluble Sinker
Dichlorobenzene (all isomers)	Aromatics, halogenated CAS 25321-22-6	Combustible w/toxic products	1B	Insoluble Sinker
o-Dichlorobenzene	Aromatics, halogenated CAS 95-50-1	Combustible w/toxic products	1B	Insoluble Sinker
m-Dichlorobenzene	Aromatics, halogenated CAS 541-73-1	Combustible w/toxic products	1B	Insoluble Sinker
p-Dichlorobenzene	Aromatics, halogenated CAS 106-46-7	Combustible w/toxic products	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
3,3'-Dichlorobenzidine	Aromatics, halogenated Amines,aryl CAS 91-94-1	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
Dichlorobromomethane	Aliphatics, halogenated CAS 75-27-4	Combustible w/toxic products	1B	Insoluble Sinker
1,4-Dichloro-2-butene	Aliphatics, halogenated CAS 764-41-0	Flammable w/toxic products	1B	Insoluble Sinker
1,1-Dichloroethane	Aliphatics, halogenated CAS 75-34-3	Flammable w/toxic products	1B	Insoluble Sinker
1,2-trans-Dichloroethylene	Aliphatics, halogenated CAS 156-60-5	Flammable w/toxic products	1B	Insoluble Sinker
Dichloropropane (all isomers)	Aliphatics, halogenated CAS 26638-19-7	Flammable w/toxic products	1B	Insoluble Sinker
1,3-Dichloropropene	Aliphatics, halogenated CAS 542-75-6	Flammable w/toxic products	1B	Insoluble Sinker
Dichloropropene (all isomers)	Aliphatics, halogenated CAS 26952-23-8	Flammable w/toxic products	1B	Insoluble Sinker
Dichloropropene-Dichloropropane mixture	Aliphatics, halogenated CAS 8003-19-8	Flammable w/toxic products	1B	Insoluble Sinker
2,2-Dichloropropionic acid	Aliphatics, halogenated CAS 75-99-0	Corrosive	2B	Soluble
Dichlorvos	Organophosphates CAS 62-73-7	Poison	1B	Insoluble Sinker
2,4-Dichlorophenol	Phenol & cresols Aromatics, halogenated CAS 120-83-2	Combustible w/toxic products	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
2,6-Dichlorophenol	Phenols & cresols Aromatics, halogenated CAS 87-65-0	Combustible w/toxic products	1B	Insoluble Sinker
Dieldrin	Epoxides Aromatics, halogenated CAS 60-57-1	Potential carcinogen	1B	Insoluble Sinker
Diethylamine	Amines, alkyl CAS 109-89-7	Flammable w/toxic products Corrosive	4B	Soluble
Diethylarsine (Note 2)	Organometallics Heavy metals CAS 692-42-2	Flammable w/toxic products	1B	Insoluble Sinker
N,N'-Diethylhydrazine	Hydrazines and hydrazides CAS 1615-80-1	Combustible w/toxic products Potential carcinogen	4B	Soluble
Diethylstilbesterol	Aromatics Ketones CAS 56-53-1	Potential carcinogen	1B	Insoluble Sinker
O,O-Diethyl-S-methyl dithiophosphate (Note 2)	Organophosphates CAS 3288-58-2		1B	Insoluble Sinker
Diethyl-p-nitrophenyl phosphate	Organophosphates Nitro compounds CAS 311-45-5		2B	Soluble
Diethyl phthalate	Esters CAS 84-66-2		1B	Insoluble Sinker
O,O-Diethyl O-pyrazinyl phosphorothioate	Organophosphates CAS 297-97-2		2B	Soluble
Dihydrosafrole (Note 2)	Aromatics Ethers CAS 94-58-6	Potential carcinogen	1B	Insoluble Sinker
Diisopropyl fluorophosphate	Organophosphates CAS 55-91-4	Corrosive	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Dimethoate	Organophosphates CAS 60-51-5	Flammable w/toxic products	2B	Soluble
3,3'-Dimethoxybenzidene	Amines, aryl CAS 119-90-4	Potential carcinogen	1B	Insoluble Sinker
alpha,alpha-Dimethylbenzylhydroperoxide	Peroxides Aromatics CAS 80-15-9	Explosive Combustible	1B	Insoluble Sinker
Dimethyl carbamoyl chloride (Note 2)	Halides, alkyl CAS 79-44-7	Combustible w/toxic products Reactive Potential carcinogen	2B	Soluble
alpha,alpha-Dimethylphenethylamine (Note 1)	Amines, aryl CAS 122-09-8		4B	Soluble
Dimethyl phthalate	Esters CAS 131-11-3	Combustible	1B	Insoluble Sinker
Dimethyl sulfate	Sulfates CAS 77-78-1	Combustible w/toxic products Corrosive Potential carcinogen	2B	Soluble
Dimethylaminoazobenzene	Azo compounds Amines, aryl CAS 60-11-7	Potential carcinogen	1B	Insoluble Sinker
7,12-Dimethylbenz[a]anthracene	Aromatics CAS 57-97-6		1B	Insoluble Sinker
3,3'-Dimethylbenzidine	Amines, aryl CAS 119-93-7	Potential carcinogen	1B	Insoluble Sinker
1,1-Dimethylhydrazine	Hydrazines and hydrazides CAS 57-14-7	Flammable w/toxic products Corrosive Potential carcinogen Poison	4B	Soluble
1,2-Dimethylhydrazine	Hydrazines and hydrazides CAS 540-73-8	Flammable w/toxic products Corrosive Potential carcinogen	4B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
2,4-Dimethylphenol	Phenols & cresols CAS 105-67-9	Combustible	3B	Insoluble Floater
Dinitrobenzene (mixed)	Nitro compounds Aromatics CAS 25154-5	Poison	1B	Insoluble Sinker
4,6-Dinitro-o-cresol	Nitro compounds Phenols & cresols CAS 534-52-1	Combustible w/toxic products	1B	Insoluble Sinker
4,6-Dinitro-o-cyclohexyl phenol	Nitro compounds Phenols & cresols CAS 131-89-5	Combustible w/toxic products	1B	Insoluble Sinker
Dinitrophenol	Nitro compounds Phenols & cresols CAS 25550-58-7	Combustible w/toxic products Poison	1B	Insoluble Sinker
2,4-Dinitrophenol	Nitro compounds Phenols & cresols CAS 51-28-5	Combustible w/toxic products Poison	1B	Insoluble Sinker
2,6-Dinitrotoluene	Nitro compounds Aromatics CAS 606-20-2		1B	Insoluble Sinker
2,4-Dinitrotoluene	Nitro compounds Aromatics CAS 121-14-2		1B	Insoluble Sinker
Dinitrotoluene	Nitro compounds Aromatics CAS 25321-14-6		1B	Insoluble Sinker
Dinoseb	Nitro compounds Phenols & cresols CAS 88-85-7	Flammable w/toxic products	1B	Insoluble Sinker
Di-n-octylphthalate	Esters CAS 117-84-0		3B	Insoluble Floater
1,4-Dioxane	Ethers CAS 123-91-1	Flammable Potential carcinogen	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
2-Diphenylhydrazine	Hydrazines and hydrazides CAS 122-66-7	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
Dipropylamine	Amines, alkyl CAS 142-84-7	Flammable w/toxic products	4B	Soluble
Diquat	Aromatics, halogenated CAS 85-00-7 CAS 2764-72-9	Combustible w/toxic products	2B	Soluble
Disulfoton	Organophosphates CAS 298-04-4	Combustible w/toxic products Poison	1B	Insoluble Sinker
2,4-Dithiobiuret	Amides, anilides, and imides CAS 541-53-7		1B	Insoluble Sinker
Diuron	Ureas Aromatics, halogenated CAS 330-54-1	Combustible w/toxic products	1B	Insoluble Sinker
Dodecylbenzenesulfonic acid	Acidic compounds, organic Aromatics CAS 27176-87-0	Combustible w/toxic products	2B	Soluble
Endosulfan	Aromatics, halogenated Sulfones, sulfoxides & sulfonates CAS 115-29-7	Combustible w/toxic products Poison	1B	Insoluble Sinker
alpha-Endosulfan	Aromatics, halogenated Sulfones, sulfoxides & sulfonates CAS 959-98-8	Poison	1B	Insoluble Sinker
beta-Endosulfan	Aromatics, halogenated Sulfones, sulfoxides & sulfonates CAS 33213-65-9	Poison	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Endosulfan sulfate	Aromatics, halogenated Sulfones, sulfoxides & sulfonates CAS 1031-07-8	Combustible w/toxic products	1B	Insoluble Sinker
Endothall (Note 1)	Acidic compounds, organic CAS 145-73-3		2B	Soluble
Endrin	Epoxides Aromatics, halogenated CAS 72-20-8	Poison	1B	Insoluble Sinker
Endrin aldehyde (Note 2)	Aldehydes CAS 930-55-2		1B	Insoluble Sinker
Epichlorohydrin	Ethers Aliphatics, halogenated CAS 106-89-8	Flammable w/toxic products	1B	Insoluble Sinker
Epinephrin	Amines, aryl CAS 51-43-4		1B	Insoluble Sinker
Ethion	Organophosphates CAS 563-12-2	Poison	1B	Insoluble Sinker
Ethyl acetate	Esters CAS 141-78-6	Flammable	4B	Soluble
Ethyl acrylate	Esters, Olefins CAS 140-88-5	Flammable Polymerizable	4B	Soluble
Ethyl carbamate	Esters CAS 51-79-6	Potential carcinogen	4B	Soluble
Ethyl cyanide	Cyanides & nitriles CAS 107-12-0	Flammable w/toxic products	4B	Soluble
Ethyl-4,4'-dichlorobenzilate (Note 1)	Esters Aliphatics, halogenated CAS 510-15-6		1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Ethyl ether	Ethers CAS 60-29-7	Explosive, upon standing Flammable	4B	Soluble
Ethyl methacrylate	Esters, Olephins CAS 97-63-2	Flammable Polymerizable	3B	Insoluble Floater
Ethyl methanesulfonate (Note 2)	Esters CAS 62-50-0		2B	Soluble
Ethylbenzene	Aromatics CAS 100-41-4	Flammable	3B	Insoluble Floater
Ethylene dibromide	Aliphatics, halogenated CAS 106-93-4	Potential carcinogen	1B	Insoluble Sinker
Ethylene dichloride	Aliphatics, halogenated CAS 107-06-2	Flammable w/toxic products Potential carcinogen	1B	Insoluble Sinker
Ethylene oxide	Oxides, alkylene CAS 75-21-8	Flammable Corrosive	4B	Soluble
Ethylenebis(dithiocarbamic acid) (Note 1)	Acidic compounds, organic CAS 111-54-6		2B	Soluble
Ethylenediamine	Amines, alkyl CAS 107-15-3	Flammable w/toxic products Corrosive	4B	Soluble
Ethylenediamine tetra acetic acid	Amines, alkyl Acidic compounds, organic CAS 60-00-4	Combustible w/toxic products	1B	Insoluble Sinker
Ethylenethiourea (Note 1)	Ureas CAS 96-45-7	Potential carcinogen	2B	Soluble
Ethylenimine	Amines, alkyl CAS 151-56-4	Flammable w/toxic products Poison	4B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Famphur (Note 2)	Organophosphates Amides, anilides, and imides CAS 52-85-7		1B	Insoluble Sinker
Ferric ammonium citrate	Organometallics CAS 1185-57-5		2B	Soluble
Ferric ammonium oxalate	Organometallics CAS 55488-87-4 CAS 2944-67-4		2B	Soluble
Ferric chloride	Halides, inorganic CAS 7705-08-0		2B	Soluble
Ferric fluoride	Halides, inorganic CAS 7783-50-8		1B	Insoluble Sinker
Ferric nitrate	Nitrates & nitrites CAS 10421-48-4	Oxidizer	2B	Soluble
Ferric sulfate	Sulfates CAS 10028-22-5		2B	Soluble
Ferrous ammonium sulfate	Sulfates CAS 10045-89-3		2B	Soluble
Ferrous chloride	Halides, inorganic CAS 7758-94-3		2B	Soluble
Ferrous sulfate	Sulfates CAS 7782-63-0 CAS 7720-78-7		2B	Soluble
Fluoranthene	Aromatics CAS 206-44-0		1B	Insoluble Sinker
Fluorene	Aromatics CAS 86-73-7		1B	Insoluble Sinker
Fluoroacetamide (Note 1)	Amides, anilides, and amides CAS 640-19-7		2B	Soluble
Formic acid	Acidic compounds, organic CAS 64-18-6	Combustible	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Fumaric acid	Acidic compounds, organic CAS 110-17-8	Combustible	1B	Insoluble Sinker
Furan	Ethers, Aromatics CAS 110-00-9	Flammable	4B	Soluble
Furfural	Aldehydes Olefins CAS 98-01-1	Combustible	2B	Soluble
Glycidaldehyde (Note 2)	Aldehydes CAS 765-34-4	Flammable Potential carcinogen	2B	Soluble
Guthion	Organophosphates Aromatics CAS 86-50-0	Poison	1B	Insoluble Sinker
Heptachlor	Aliphatics, halogenated CAS 76-44-8	Potential carcinogen	1B	Insoluble Sinker
Heptachlor epoxide	Aliphatics, halogenated Epoxides CAS 1024-57-3	Potential carcinogen	1B	Insoluble Sinker
Hexachlorobenzene	Aromatics, halogenated CAS 118-74-1	Potential carcinogen	1B	Insoluble Sinker
Hexachlorobutadiene	Aliphatics, halogenated Olefins CAS 87-68-3		1B	Insoluble Sinker
Hexachlorocyclopentadiene	Aliphatics, halogenated Olefins CAS 77-47-4		1B	Insoluble Sinker
Hexachloroethane	Aliphatics, halogenated CAS 67-72-1		1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Hexachlorohexahydro-endo-endo-dimethano-naphthalene	Aromatics, halogenated CAS 465-73-6	Poison	1B	Insoluble Sinker
Hexachlorophene	Aromatics, halogenated CAS 70-30-4		1B	Insoluble Sinker
Hexachloropropene (Note 2)	Aliphatics, halogenated Olefins CAS 1888-71-7		1B	Insoluble Sinker
Hexaethyl tetraphosphate	Organophosphates CAS 757-58-4	Poison	2B	Soluble
Hydrazine	Hydrazines and hydrazides CAS 302-01-2	Flammable w/toxic products Corrosive Potential carcinogen Poison	2B	Soluble
Hydrochloric acid	Acidic compounds, inorganic CAS 7647-01-0	Corrosive Reactive	2B	Soluble
Hydrocyanic acid	Cyanides & nitriles Acidic compounds, inorganic CAS 74-90-8	Flammable w/toxic products Poison	4B	Soluble
Hydrofluoric acid	Acidic compounds, inorganic CAS 7664-39-3	Corrosive Reactive	4B	Soluble
Indeno(1,2,3-cd)pyrene	Aromatics CAS 193-39-5	Potential carcinogen	1B	Insoluble Sinker
Iron dextran	Organometallics CAS 9004-66-4	Potential carcinogen	2B	Soluble
Isobutyl alcohol	Alcohols & glycols CAS 78-83-1	Flammable	4B	Soluble
Isophorone	Ketones CAS 78-59-1	Combustible	4B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Isoprene	Olephins CAS 78-79-5	Flammable Polymerizable	3B	Insoluble Floater
Isopropanolamine dodectyl benzenesulfonate	Sulfones, sulfoxides, & sulfonates CAS 42504-46-1	Combustible w/toxic products	1B	Insoluble Sinker
Isosafrole (Note 2)	Aromatics Ethers CAS 120-58-1	Potential carcinogen	1B	Insoluble Sinker
Kelthane	Aromatics, halogenated CAS 115-32-2	Combustible w/toxic products	1B	Insoluble Sinker
Kepone	Aliphatics, halogenated Ketones CAS 143-50-0	Combusible w/toxic products Potential carcinogen	1B	Insoluble Sinker
Lasocarpine (Note 2)	Acidic compounds, organic CAS 303-34-4	Potential carcinogen	1B	Insoluble Sinker
Lead	Heavy metals CAS 7439-92-1		1B	Insoluble Sinker
Lead acetate	Organometallics Heavy metals CAS 301-04-2	Potential carcinogen	2B	Soluble
Lead arsenate	Heavy metals CAS 3687-31-8 CAS 7784-40-9 CAS 7645-25-2 CAS 10102-48-4	Poison	1B	Insoluble Sinker
Lead chloride	Halides, inorganic Heavy metals CAS 7758-95-4		1B	Insoluble Sinker
Lead fluoborate	Halides, inorganic Heavy metals CAS 13814-96-5		2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Lead fluoride	Halides, inorganic Heavy metals CAS 7783-46-2		1B	Insoluble Sinker
Lead iodide	Halides, inorganic Heavy metals CAS 10101-63-0		1B	Insoluble Sinker
Lead nitrate	Nitrates & nitrites Heavy metals CAS 10099-74-8	Oxidizer	2B	Soluble
Lead phosphate	Phosphates and phosphonates Heavy metals CAS 7446-27-7	Potential carcinogen	1B	Insoluble Sinker
Lead stearate	Organometallics Heavy metals CAS 7428-48-0 CAS 1072-35-1 CAS 56189-09-4		1B	Insoluble Sinker
Lead subacetate	Organometallics Heavy metals CAS 1335-32-6	Potential carcinogen	2B	Soluble
Lead sulfate	Sulfates Heavy metals CAS 15739-80-7 CAS 7446-14-2		1B	Insoluble Sinker
Lead sulfide	Sulfides and mercaptans Heavy metals CAS 1314-87-0		1B	Forms toxic hydrogen sulfide
Lead thiocyanate	Cyanates Heavy metals CAS 592-87-0		1B	Insoluble Sinker
Lindane	Aliphatics, halogenated CAS 58-89-9	Potential carcinogen	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Lithium chromate	Chromates CAS 14307-35-8		2B	Soluble
Malathion	Organophosphates CAS 121-75-5		1B	Insoluble Sinker
Maleic acid	Acids, organic CAS 110-16-7		2B	Soluble
Maleic anhydride	Acids, organic CAS 108-31-6	Combustible	2B	Soluble
Maleic hydrazide	Hydrazines and hydrazides CAS 123-33-1	Combustible w/toxic products	1B	Insoluble Sinker
Malononitrile	Cyanides & nitriles CAS 109-77-3	Combustible w/toxic products	2B	Soluble
Melphalan	Aromatics, halogenated Amines, aryl CAS 148-82-3	Potential carcinogen	1B	Insoluble Sinker
Mercaptodimethur	Sulfides and mercaptans CAS 2032-65-7		1B	Insoluble Sinker
Mercuric cyanide	Cyanides & nitriles Heavy metals CAS 592-04-1	Poison	2B	Soluble
Mercuric nitrate	Nitrates & nitrites Heavy metals CAS 10045-94-0	Oxidizer	2B	Soluble
Mercuric sulfate	Sulfates Heavy metals CAS 7783-35-9	Poison	1B	Insoluble Sinker
Mercuric thiocyanate	Cyanates Heavy metals CAS 592-85-8	Poison	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Mercurous nitrate	Nitrates & nitrites Heavy metals CAS 7782-86-7 CAS 10415-75-5	Oxidizer	2B	Soluble
Mercury	Heavy metals CAS 7439-97-6		1B	Insoluble Sinker
Mercury fulminate	Cyanides & nitriles Heavy metals CAS 628-86-4	Explosive	1B	Insoluble Sinker
Methacrylonitrile	Cyanides & nitriles CAS 126-98-7	Flammable w/toxic products Polymerizable	4B	Soluble
Methanol	Alcohols and glycols CAS 67-56-1	Flammable	4B	Soluble
Methapyriline (Note 1)	Amines, aryl CAS 91-80-5		2B	Soluble
Methomyl	Amides, anilides, and imides CAS 16752-77-5		2B	Soluble
Methoxychlor	Aromatics, halogenated CAS 72-43-5		1B	Insoluble Sinker
Methyl bromide	Halides, alkyl CAS 74-83-9	Combustible w/toxic products Poison	1B	Insoluble Sinker
Methyl chlorocarbonate	Ethers Aliphatics, halogenated CAS 79-22-1	Flammable w/toxic products	2B	Soluble
Methyl chloroform	Halides, alkyl CAS 71-55-6	Combustible w/toxic products	1B	Insoluble Sinker
Methyl ethyl ketone	Ketones CAS 78-93-3	Flammable	4B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Methyl hydrazine	Hydrazines and hydrazides CAS 60-34-4	Flammable w/toxic products Poison	4B	Soluble
Methyl iodide	Halides, alkyl CAS 74-88-4	Potential carcinogen	2B	Soluble
Methyl isobutyl ketone	Ketones CAS 108-10-1	Flammable	4B	Soluble
Methyl isocyanate	Cyanates CAS 624-83-9	Flammable w/toxic products	4B	Exothermic Reaction
Methyl methacrylate	Esters, Olefins CAS 80-62-6	Flammable Polymerizable	4B	Soluble
Methyl parathion	Organophosphates CAS 298-00-0	Combustible w/toxic products Poison	1B	Insoluble Sinker
3-Methylcholanthrene	Aromatics CAS 56-49-5	Potential carcinogen	1B	Insoluble Sinker
Methylene bromide	Halides, alkyl CAS 74-95-3		2B	Soluble
Methylene chloride	Halides, alkyl CAS 75-09-2	Combustible w/toxic products	2B	Soluble
4,4'-Methylenebis(2-chloro-aniline) (Note 2)	Aromatics, halogenated Amines, aryl CAS 101-14-4	Potential carcinogen	1B	Insoluble Sinker
Methylthiouracil (Note 1)	Amines, alkyl CAS 56-04-2	Potential carcinogen	1B	Insoluble Sinker
N-Methyl-N'-nitro-N-nitrosoguanidine (Notes 1,2)	Nitro compounds Nitroso compounds CAS 70-25-7	Flammable w/toxic products Potential carcinogen	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Mevinphos	Organophosphates CAS 7786-34-7	Combustible w/toxic products Poison	2B	Soluble
Mexacarbate	Esters CAS 315-18-4	Combustible w/toxic products Poison	1B	Insoluble Sinker
Mitomycin C (Note 1)	(See mitomycin) CAS 50-07-7	Potential carcinogen	2B	Soluble
Monoethylamine	Amines, alkyl CAS 75-04-7	Flammable w/toxic products Corrosive	4B	Soluble
Naled	Aliphatics, halogenated Organophosphates CAS 300-76-5	Combustible w/toxic products	1B	Insoluble Sinker
Naphthalene	Aromatics CAS 91-20-3	Combustible	1B	Insoluble Sinker
Naphthenic acid	Acidic compounds, organic CAS 1338-24-5	Combustible	3B	Insoluble Floater
1,4-Naphthoquinone	Aromatics CAS 130-15-4		2B	Soluble
2-Naphthylamine	Amines, aryl CAS 91059-8	Potential carcinogen	2B	Soluble
1-Naphthylamine	Amines, aryl CAS 134-32-7		1B	Insoluble Sinker
alpha-Naphthylthiourea	Ureas CAS 86-88-4		1B	Insoluble Sinker
Nickel	Heavy metals CAS 7440-02-0	Flammable w/toxic products Potential carcinogen	1B	Insoluble Sinker
Nickel ammonium sulfate	Sulfates Heavy metals CAS 15699-18-0		2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Nickel carbonyl	Organometallics Heavy metals CAS 13463-39-3	Flammable w/toxic products Reactive Potential carcinogen	1B	Insoluble Sinker
Nickel chloride	Halides, inorganic Heavy metals CAS 7718-54-9 CAS 37211-05-5		2B	Soluble
Nickel cyanide	Cyanides and nitriles Heavy metals CAS 557-19-7	Poison	1B	Insoluble Sinker
Nickel hydroxide	Basic compounds Heavy metals CAS 12054-48-7		1B	Insoluble Sinker
Nickel nitrate	Nitrates and nitrites Heavy metals CAS 14216-75-2	Oxidizer	2B	Soluble
Nickel sulfate	Sulfates Heavy metals CAS 7786-81-4		2B	Soluble
Nicotine and salts	Amines, aryl CAS 54-11-5	Combustibel w/toxic products Poison	2B	Soluble
Nitric acid	Acidic compounds, inorganic CAS 7697-37-2	Corrosive Reactive Oxidizer	2B	Soluble
p-Nitroaniline	Nitro compounds Amines, aryl CAS 100-01-6	Poison	1B	Insoluble Sinker
Nitrobenzene	Nitro compounds Aromatics CAS 98-95-3	Combustible w/toxic products Poison	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Nitrogen dioxide	Acidic compounds, inorganic CAS 10102-44-0	Corrosive Oxidizer Poison	2B	Decomposes (Sinker)
Nitroglycerine	Nitro compounds CAS 55-63-0	Explosive Flammable w/toxic products	1B	Insoluble Sinker
4-Nitrophenol	Nitro compounds Phenols and cresols CAS 100-02-7	Combustible w/toxic products	2B	Soluble
2-Nitrophenol	Nitro compounds Phenols and cresols CAS 88-75-5	Combustible w/toxic products	1B	Insoluble Sinker
Nitrophenol (mixed)	Nitro compounds Phenols and cresols CAS 25154-55-6	Combustible w/toxic products	2B	Soluble
2-Nitropropane	Nitro compounds CAS 79-46-9	Flammable w/toxic products	4B	Soluble
N-Nitrosodi-n-butylamine	Nitroso compounds CAS 924-16-3	Combustible w/toxic products Potential carcinogen	2B	Soluble
N-Nitrosodiethanolamine	Nitroso compounds CAS 1116-54-7	Combustible w/toxic products Potential carcinogen	2B	Soluble
N-Nitrosodiethylamine	Nitroso compounds CAS 55-18-5	Combustible w/toxic products Potential carcinogen	4B	Soluble
N-Nitrosodimethylamine	Nitroso compounds CAS 62-75-9	Flammable w/toxic products Potential carcinogen	2B	Soluble
N-Nitrosodiphenylamine	Nitroso compounds Amines, aryl CAS 86-30-6	Potential carcinogen	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
N-Nitrosodi-n-propylamine	Nitroso compound CAS 621-64-7	Combustible w/toxic products Potential carcinogen	3B	Insoluble Floater
N-Nitroso-N-ethylurea (Note 2)	Nitroso compounds CAS 759-73-9	Potential carcinogen	2B	Soluble
N-Nitroso-N-methylurea (Note 1)	Nitroso compounds CAS 684-93-5	Combustible w/toxic products Potential carcinogen	2B	Soluble
N-Nitroso-N-methylurethane (Note 2)	Nitroso compounds CAS 615-53-2	Combustible w/toxic products Potential carcinogen	2B	Soluble
N-Nitrosomethylvinylamine	Nitroso compounds CAS 4549-40-0	Flammable w/toxic products Potential carcinogen	2B	Soluble
N-Nitrosopiperidine	Nitroso compounds CAS 100-75-4	Potential carcinogen	2B	Soluble
N-Nitrosopyrrolidine	Nitroso compounds CAS 930-55-2	Combustible w/toxic products Potential carcinogen	2B	Soluble
Nitrotoluene	Nitro compounds Aromatics CAS 1321-12-6	Combustible w/toxic products	1B	Insoluble Sinker
5-Nitro-o-toluidine (Note 2)	Nitro compounds Aromatics CAS 99-55-8		1B	Insoluble Sinker
Octamethylpyrophosphoramide	Amides, anilides, and imides Organophosphates CAS 152-16-9		2B	
Osmium tetroxide	Oxides Heavy metals CAS 20816-12-0		2B	Soluble
Paraformaldehyde	Aldehydes CAS 30525-89-4	Combustible	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Paraldehyde	Aldehydes CAS 123-63-7	Flammable	4B	Soluble
Parathion	Organophosphates CAS 56-38-2	Poison	1B	Insoluble Sinker
Pentachlorobenzene	Aromatics, halogenated CAS 608093-5	Combustible w/toxic products	1B	Insoluble Sinker
Pentachloroethane	Aliphatics, halogenated CAS 76-01-7	Combustible w/toxic products	1B	Insoluble Sinker
Pentachloronitrbenzene	Nitro compounds Aromatics, halogenated CAS 82-68-8		1B	Insoluble Sinker
Pentachlorophenol	Phenols and cresols Aromatics, halogenated CAS 87-86-5		1B	Insoluble Sinker
1,3-Pentadiene	Olephins CAS 504-60-9	Flammable	3B	Insoluble Floater
Phenacetin	Aromatics Amides, anilides, and imides CAS 62-44-2	Potential carcinogen	1B	Insoluble Sinker
Phenanthrene	Aromatics CAS 85-01-8		1B	Insoluble Sinker
Phenol	Phenols and cresols CAS 108-95-2	Combustible Corrosive Poison	2B	Soluble
Phenyl dichloroarsine	Aromatics, halogenated Heavy metals CAS 696-28-6	Poison	1B	Insoluble Sinker
Phenylmercuric acetate	Organometallics Heavy metals CAS 62-38-4	Combustible w/toxic products	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
N-Phenylthiourea	Ureas Aromatics CAS 103-85-5		1B	Insoluble Sinker
Phorate	Organophosphates CAS 298-02-2		1B	Insoluble Sinker
Phosphoric acid	Acids, inorganic CAS 7664-38-2	Corrosive	2B	Soluble
Phosphorus	Phosphorous and compounds CAS 7723-14-0	Flammable w/toxic products Poison	1B	Insoluble Sinker
Phosphorus oxychloride	Phosphorous and compounds Halides, inorganic CAS 10025-87-3	Corrosive Reactive	2B	Reacts violently to give off HCl
Phosphorus pentasulfide	Phosphorous and compounds Sulfides and mercaptans CAS 1314-80-3	Flammable w/toxic products Reactive	2B	Forms hydrogen sulfide on contact
Phosphorus trichloride	Phosphorous and compounds Halides, inorganic CAS 7719-12-2	Corrosive Reactive	2B	Reacts violently to give off HCl
Phthalic anhydride	Aromatics CAS 85-44-9	Corrosive	1B	Insoluble Sinker
2-Picoline	Amines, aryl CAS 109-06-8	Combustible w/toxic products		Soluble
Polychlorinated biphenyls	Aromatics, halogenated CAS 1336-36-3	Potential carcinogen	1B	Insoluble Sinker
Potassium arsenate	Heavy metals CAS 7784-41-0	Poison	2B	Soluble
Potassium arsenite	Heavy metals CAS 10124-50-2	Poison	2B	
Potassium bichromate	Chromates CAS 7778-50-9	Corrosive Oxidizer	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Potassium chromate	Chromates CAS 7789-00-6		2B	Soluble
Potassium cyanide	Cyanides and nitriles CAS 151-50-8	Poison	2B	Produces cyanide ion on contact
Potassium hydroxide	Basic compounds CAS 1310-58-3	Corrosive	2B	Generates heat on contact
Potassium permanganate	Basic compounds CAS 7722-64-7	Corrosive Oxidizer	2B	Soluble
Potassium silver cyanid	Cyanides and nitriles Heavy metsals CAS 506-61-6		2B	Soluble
Pronamide (Note 2)	Aromatics, halogenated Amides, anilides, and imides CAS 23950-58-5		1B	Insoluble Sinker
1,3-Propane sultone	Sulfones,sulfoxides and sulfonates CAS 1120-71-4	Potential carcinogen	2B	Soluble
Propargite	Sulfites Aromatics CAS 2312-35-8	Flammable w/toxic products	1B	Insoluble Sinker
Propargyl alcohol	Alcohols & glycols CAS 107-19-7	Flammable Poison	4B	Soluble
Propionic acid	Acidic compounds, organic CAS 79-09-4	Combustible	4B	Soluble
Propionic anhydride	Acidic compounds, organic CAS 123-62-6	Combustible	2B	Decomposes (Sinker)
n-Propylamine	Amines, alkyl CAS 107-10-8	Flammable w/toxic products	4B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Propylene dichloride	Aliphatics, halogenated CAS 78-87-5	Flammable w/toxic products	1B	Insoluble Sinker
Propylene oxide	Oxides, alkylene CAS 75-56-9	Flammable Corrosive	4B	Soluble
1,2-Propylenimine	Amines, alkyl CAS 75-55-8	Flammable w/toxic products Potential carcinogen	4B	Soluble
Pyrene	Aromatics CAS 129-00-0	Combustible w/toxic products	1B	Insoluble Sinker
Pyrethrins	Acidic compounds, organic CAS 121-21-1 CAS 121-29-9	Combustible w/toxic products	1B	Insoluble Sinker
4-Pyridinamine (Note 2)	Amines, alkyl CAS 504-24-5	Combustible w/toxic products	2B	Soluble
Pyridine	Amines, aryl CAS 110-86-1	Flammable w/toxic products	4B	Soluble
Quinoline	Amines, aryl CAS 91-22-5	Combustible	2B	Soluble
Reserpine	Aromatics CAS 50-55-5		1B	Insoluble Sinker
Resorcinol	Aromatics CAS 108-46-3	Combustible	2B	Soluble
Saccharin	Sulfones,sulfoxides and sulfonates Aromatics CAS 81-07-2	Potential carcinogen	3B	Insoluble Floater
Safrole	Aromatics Ethers CAS 94-59-7	Combustible Potential carcinogen	1B	Insoluble Sinker
Selenious acid	Acidic compounds, inorganic Heavy metals CAS 7783-00-8		2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Selenium	Heavy metals CAS 7782-49-2	Combustible w/toxic products		Insoluble Sinker
Selenium disulfide	Sulfides and mercaptans Heavy metals CAS 7488-56-4	Reactive	1B	Forms hydrogen sulfide on contact
Selenium oxide	Oxides Heavy metals CAS 7446-08-4	Poison	2B	Soluble
Selenourea (Note 2)	Ureas Heavy metals CAS 630-10-4		2B	Soluble
Silver	Heavy metals CAS 7440-22-4		1B	Insoluble Sinker
Silver cyanide	Cyanides and nitriles Heavy metals CAS 506-64-9	Poison	1B	Insoluble Sinker
Silver nitrate	Nitrates and nitrites Heavy metals CAS 7761-88-8	Oxidizer	2B	Soluble
Sodium	Alkali metals CAS 7440-23-5	Flammable Corrosive Reactive	4B	Inflames on contact
Sodium arsenate	Heavy metals CAS 7631-89-2	Poison	2B	Soluble
Sodium arsenite	Heavy metals CAS 7784-46-5	Poison	2B	Soluble
Sodium azide	Azo compounds CAS 26628-22-8	Combustible w/toxic products Poison Explosive		Soluble
Sodium bichromate	Chromates CAS 10588-01-9	Corrosive Oxidizer	2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Sodium bifluoride	Halides, inorganic CAS 1333-83-1	Corrosive	2B	Soluble
Sodium bisulfite	Sulfites CAS 7631-90-5		2B	Soluble
Sodium chromate	Chromates CAS 7775-11-3		2B	Soluble
Sodium cyanide	Cyanides and nitriles CAS 143-33-9	Poison	2B	Soluble
Sodium dodecylbenzene sulfonate (Note 2)	Sulfones,sulfoxides and sulfonates CAS 25155-30-0		2B	Soluble
Sodium fluoracetate	Organometallics CAS 62-74-8		2B	Soluble
Sodium fluoride	Halides, inorganic CAS 7681-49-4		2B	Reacts to form hydrogen fluoride
Sodium hydrosulfide	Sulfides and mercaptans CAS 16721-80-5	Flammable w/toxic products Reactive	2B	Soluble
Sodium hydroxide	Basic compounds CAS 1310-73-2	Corrosive Reactive	2B	Generates heat on contact
Sodium hypochlorite	Halides, inorganic CAS 10022-70-5 CAS 7681-52-9		2B	Soluble
Sodium methylate	Organometallics CAS 124-41-4	Flammable w/toxic products Reactive	2B	Soluble
Sodium nitrite	Nitrates and nitrites CAS 7632-00-0	Oxidizer	2B	Soluble
Sodium phosphate, dibasic	Phosphates and phosphonates CAS 7558-79-4 CAS 10039-32-4 CAS 10028-24-7 CAS 10140-65-5		2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Sodium phosphate, tribasic	Phosphates and phosphonates CAS 7601-54-9 CAS 7785-84-4 CAS 10101-89-0 CAS 10361-89-4 CAS 7758-29-4 CAS 10124-56-8		2B	Soluble
Sodium selenite	Heavy metals CAS 10102-18-8 CAS 7782-82-3	Poison	2B	Soluble
Streptozotocin (Note 1)	(See streptozotocin CAS 18883-66-4	Potential carcinogen	2B	Soluble
Strontium chromate	Chromates Heavy metals CAS 7789-06-2			Insoluble Sinker
Strontium sulfide	Sulfides and mercaptans Heavy metals CAS 1314-96-1	Reactive	1B	Reacts to give toxic hydrogen sulfide
Strychnine and salts	(See strychnine and salts) CAS 57-24-9	Poison	1B	Insoluble Sinker
Styrene	Aromatics, Olefins CAS 100-42-5	Flammable Polymerizable	3B	Insoluble Floater
Sulfur monochloride	Halides, inorganic CAS 12771-08-3	Corrosive Reactive	2B	Decomposes (Sinker)
Sulfuric acid	Acidic compounds, inorganic CAS 7664-93-9	Corrosive Reactive	2B	Soluble with evolution of heat
sym-Trinitrobenzene	Nitro compounds Aromatics CAS 99-35-4	Flammable w/toxic products Explosive	1B	Insoluble Sinker
2,4,5-T acid	Aromatics, halogenated CAS 93-73-5		1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
2,4,5-T amines	Amines, aryl Aromatics, halogenated CAS 2008-46-0	Combustible w/toxic products	1B	Insoluble Sinker
2,4,5-T esters	Esters Aromatics, halogenated CAS N.A.		1B	Insoluble Sinker
2,4,5-T salts	Aromatics, halogenated CAS 13560-99-1	Combustible w/toxic products	2B	Soluble
1,2,4,5-Tetrachlorobenzene	Aromatics, halogenated CAS 95-94-3		1B	Insoluble Sinker
1,1,1,2-Tetrachloroethane	Aliphatics, halogenated CAS 630-20-6		1B	Insoluble Sinker
1,1,2,2-Tetrachloroethane	Aliphatics, halogenated CAS 79-34-5		1B	Insoluble Sinker
2,3,4,6-Tetrachlorophenol	Aromatics, halogenated Phenols and cresola CAS 58-90-2	Combustible w/toxic products	1B	Insoluble Sinker
2,3,7,8-Tetrachlorodibenzo-p-dioxin	Aromatics, halogenated CAS 1746-01-6	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
Tetrachloroethylene	Aliphatics, halogenated Olefins CAS 127-18-4		1B	Insoluble Sinker
Tetraethyldithiopyrophosphate	Organophosphates CAS 3689-24-5	Poison	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Tetraethyl lead	Organometallics Heavy metals CAS 78-00-2	Combustible w/toxic products Poison	1B	Insoluble Sinker
Tetraethyl pyrophosphate	Organophosphates CAS 107-49-3	Combustible w/toxic products Poison	2B	Soluble
Tetrahydrofuran	Ethers CAS 109-99-9	Flammable	4B	Soluble
Tetranitromethane	Nitro compounds CAS 509-14-8	Explosive Oxidizer	1B	Insoluble Sinker
Thallium	Heavy metals CAS 7440-28-0		1B	Insoluble Sinker
Thallium(I) acetate	Organometallics CAS 563-68-8		2B	Soluble
Thallium(I) carbonate	Organometallics Heavy metals CAS 6533-73-9		2B	Soluble
Thallium (I) chloride	Halides, inorganic Heavy metals CAS 7791-12-0	Poison	1B	Insoluble Sinker
Thallium(I) nitrate	Nitrates and nitrites Heavy metals CAS 10102-45-1	Oxidizer	2B	Soluble
Thallium (III) oxide	Oxides Heavy metals CAS 1314-32-5	Oxidizer	1B	Insoluble Sinker
Thallium (I) selenide	Heavy metals CAS 12039-52-0		1B	Insoluble Sinker
Thallium(I) sulfate	Sulfates Heavy metals CAS 7446-18-6	Poison	2B	Soluble
1-(o-Chlorophenyl)-thiourea (Note 2)	Aromatics, halogenated Ureas CAS 5344-82-1		2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Thioacetamide (Note 2)	Amides, anilides, and imides CAS 62-55-5	Potential carcinogen	2B	Soluble
Thiofanox (Note 2)	Sulfides and mercaptans Amides, anilines, and imides CAS 39196-1804		2B	Insoluble Sinker
Thiophenol	Phenols and cresols CAS 108-98-5		1B	Insoluble Sinker
Thiosemicarbazide (Note 1)	Azo compounds Ureas CAS 79-19-6		2B	Soluble
Thiourea	Ureas CAS 62-56-6	Potential carcinogen	2B	Soluble
Thiram	Sulfides and mercaptans CAS 137-26-8	Combustible w/toxic products	1B	Insoluble Sinker
Toluene	Aromatics CAS 108-88-3	Flammable	3B	Insoluble Floater
Toluene diisocyanate	Cyanates Aromatics CAS 584-84-9	Combustible w/toxic products Poison	2B	Decomposes (Sinker)
Toluenediamine	Amines, aryl CAS 95-80-7	Potential carcinogen	2B	Soluble
o-Toluidine hydrochloride	Aromatics, halogenated Amines, aryl CAS 636-21-5	Potential carcinogen	2B	Soluble
Toxaphene	Aliphatics, halogenated CAS 8001-35-2	Combustible w/toxic products Potential carcinogen	1B	Insoluble Sinker
2,4,5-TP acid	Acidic compounds, organic Aromatics, halogenated CAS 93-72-1	Combustible w/toxic products	1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
2,4,5-TP acid esters	Esters, Aromatics, halogenated CAS N.A.	Combustible w/toxic products	1B	Insoluble Sinker
Tris(2,3-dibromopropyl) phosphate (Note 2)	Phosphates and phosphonates CAS 126-72-7	Potential carcinogen	1B	Insoluble Sinker
Trichlorfon	Aliphatics, halogenated Organophosphates CAS 52-68-6		2B	Soluble
1,2,4-Trichlorobenzene	Aromatics, halogenated CAS 120-82-1	Combustible w/toxic products	1B	Insoluble Sinker
1,1,2-Trichloroethane	Aliphatics, halogenated CAS 79-00-5	Combustible w/toxic products	1B	Insoluble Sinker
Trichloroethylene	Aliphatics, halogenated CAS 79-01-6	Flammable w/toxic products	1B	Insoluble Sinker
Trichloromethanesulfenyl chloride (Note 2)	Aliphatics, halogenated CAS 594-42-3	Poison	1B	Insoluble Sinker
Trichloromonofluoromethane	Aliphatics, halogenated CAS 75-69-4		1B	Insoluble Sinker
2,4,5-Trichlorophenol	Phenols and cresols Aromatics, halogenated CAS 95-95-4	Combustible w/toxic products	1B	Insoluble Sinker
2,4,6-Trichlorophenol	Phenols and cresols Aromatics, halogenated CAS 88-06-2	Combustible w/toxic products	1B	Insoluble Sinker
Trichlorophenol	Phenols and cresols Aromatics, halogenated CAS 25167-82-2		1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Triethanolamine dodecylbenzene sulfonate	Sulfones,sulfoxides and sulfonates CAS 27323-41-7		2B	Soluble
Triethylamine	Amines, alkyl CAS 121-44-8	Flammable w/toxic products Corrosive	4B	Soluble
Trypan blue (Note 2)	Azo compounds CAS 72-57-1	Potential carcinogen	2B	Soluble
Uracil mustard	Aliphatics, halogenated Amines, alkyl CAS 66-75-1	Potential carcinogen	1B	Insoluble Sinker
Uranyl acetate	Organometallics Heavy metals CAS 541-09-3	Radioactive	2B	Soluble
Uranyl nitrate	Nitrates and nitrites Heavy metals CAS 10102-06-4 CAS 36478-76-9	Radioactive Oxidizer	2B	Soluble
Vanadium pentoxide	Oxides Heavy metals CAS 1314-62-1		1B	Insoluble Sinker
Vanadyl sulfate	Sulfates Heavy Metals CAS 27774-13-6		2B	Soluble
Vinyl acetate	Esters, Olefins CAS 108-05-4	Flammable Polymerizable	4B	Soluble
Vinylidene chloride	Aliphatics, halogenated CAS 75-35-4	Flammable w/toxic products Polymerizable Potential carcinogen	1B	Insoluble Sinker
Warfarin	Aromatics CAS 81-81-2		1B	Insoluble Sinker

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Xylene	Aromatics CAS 1330-20-7	Flammable	3B	Insoluble Floater
Xylenol	Phenols and cresols CAS 1300-71-6	Combustible	2B	Soluble
Zinc	Heavy metals CAS 744066-6	Combustible	1B	Insoluble Sinker
Zinc acetate	Organometallics Heavy metals CAS 557-34-6		2B	Soluble
Zinc ammonium chloride	Halides, inorganic Heavy metals CAS 52628-25-8 CAS 14639-97-5 CAS 14639-98-6		2B	Soluble
Zinc borate	Heavy metals CAS 1332-07-6		2B	Soluble
Zinc bromide	Halides, inorganic Heavy metals CAS 7699-45-8		2B	Soluble
Zinc carbonate	Organometallics Heavy metals CAS 3486-35-9		1B	Insoluble Sinker
Zinc chloride	Halides, inorganic Heavy metals CAS 7646-85-7		2B	Soluble
Zinc cyanide	Cyanides and nitriles Heavy metals CAS 557-21-1	Poison	1B	Insoluble Sinker
Zinc fluoride	Halides, inorganic Heavy metals CAS 7783-49-5		1B	Insoluble Sinker
Zinc formate	Organometallics Heavy metals CAS 557-41-5		2B	Soluble
Zinc hydrosulfite	Sulfites Heavy metals CAS 7779-86-4		2B	Soluble

TABLE 1A. RELEASES IN WATER

* "B" Table Reference

Hazardous Substance	Chemical Class/ CAS No.	Hazard(s) In Addition To Toxicity	*	Behavior in Water
Zinc nitrate	Nitrates and nitrites Heavy metals CAS 7779-88-6	Oxidizer	2B	Soluble
Zinc phenolsulfonate	Phenols and cresols Heavy metals CAS 127-82-2	Combustible w/toxic products	2B	Soluble
Zinc phosphide	Phosphorous and compounds Heavy metals CAS 1314-84-7	Flammable w/toxic products Reactive Poison	1B	Insoluble Sinker
Zinc silicofluoride	Halides, inorganic Heavy metals CAS 16871-71-9		2B	Soluble
Zinc sulfate	Sulfates Heavy metals CAS 7733-02-0		2B	Soluble
Zirconium nitrate	Nitrates and nitrites Heavy metals CAS 13746-89-9	Oxidizer	2B	Soluble
Zirconium potassium fluoride	Halides, inorganic Heavy metals CAS 16923-95-8		2B	Soluble
Zirconium sulfate	Sulfates Heavy metals CAS 14644-61-2		2B	Soluble
Zirconium tetrachloride	Halides, inorganic Heavy metals CAS 10026-11-6	Corrosive Reactive	2B	Soluble

Note 1: Specific gravity calculated according to Grains Method given in the Handbook of Chemical Property Estimation Methods.

Note 2: Specific gravity and/or solubility estimated based on active chemical groups and physical characteristics of structurally similar compounds.

LEGEND: N/A = Not available

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Acetaldehyde	Aldehydes	75-07-0	Flammable Polymerizable
Acetic acid	Acidic compounds, organic	64-19-7	Combustible Corrosive
Acetic anhydride	Acidic compounds, organic	108-24-7	Combustible Corrosive
Acetone	Ketones	67-64-1	Flammable
Acetone cyanohydrin	Cyanides and nitriles	75-86-5	Combustible w/toxic products Poison
Acetonitrile	Cyanides and nitriles	75-05-8	Flammable w/toxic products
Acetophenone	Ketones	98-86-2	Combustible
Acetyl bromide	Aliphatics, halogenated	506-96-7	Flammable w/toxic products Corrosive Reactive
Acetyl chloride	Aliphatics, halogenated	75-36-5	Flammable w/toxic products Corrosive Reactive
Acrolein	Aldehydes, Olefins	107-02-8	Flammable Polymerizable Poison
Acrylic acid	Acidic compounds, organic, Olefins	79-10-7	Combustible Corrosive Polymerizable
Acrylonitrile	Cyanides and nitriles	107-13-1	Flammable w/toxic products Polymerizable Potential carcinogen Poison
Allyl alcohol	Alcohols and glycols, Olefins	107-18-6	Flammable Poison
Allyl chloride	Halides, alkyl, Olefins	107-05-1	Flammable w/toxic products

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Ammonium hydroxide	Basic compounds	1336-21-6	Corrosive
Ammonium sulfide (in aqueous solution)	Sulfides and mercaptans	12135-76-1	Flammable w/toxic products
Amyl acetate	Esters	628-63-7	Flammable
Aniline	Amines, aryl	62-53-3	Combustible w/toxic products Poison
Antimony pentachloride	Halides, inorganic, Heavy metals	7647-18-9	Corrosive Reactive
Arsenic trichloride	Halides, inorganic, Heavy metals	7784-34-1	Corrosive Reactive Poison
Benzal chloride	Aromatics, halogenated	98-87-3	
Benzene	Aromatics	71-43-2	Flammable Potential carcinogen
Benzenesulfonyl chloride	Acidic compounds, organic	98-09-9	Combustible w/toxic products
Benzonitrile	Cyanides and nitriles	100-47-0	Combustible w/toxic products
Benzotrichloride	Aromatics, halogenated	98-07-7	Combustible w/toxic products Corrosive
Benzoyl chloride	Aromatics, halogenated	98-88-4	Combustible w/toxic products Corrosive
Benzyl chloride	Aromatics, halogenated	100-44-7	Combustible w/toxic products Corrosive Reactive
2,2'-Bioxirane	Epoxides	1464-53-5	Potential carcinogen
Bis(2-chloroethoxy) methane	Aliphatics, halogenated	111-91-1	
Bis(2-chloroethyl) ether	Ethers	111-44-4	Combustible w/toxic products Poison

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Bis(2-chloroisopropyl)-ether	Ethers, Aliphatics, halogenated	108-60-1	Combustible w/toxic products
Bis(chloromethyl) ether	Ethers	542-88-1	Combustible w/toxic products Potential carcinogen
Bis(2-ethylhexyl) phthalate	Esters	117-81-7	
Bromoacetone (Note 2)	Ketones	598-31-2	Poison
Bromoform	Halides, alkyl	75-25-2	
4-Bromophenyl phenyl ether	Ethers, Aromatics, halogenated	101-55-3	Combustible w/toxic products
1-Butanol	Alcohols and glycols	71-36-3	Flammable
2-Butanone peroxide (Note 2)	Peroxides	1338-23-4	Explosive Oxidizer Combustible
Butyl acetate	Esters	123-86-4	Flammable
Butyl benzyl phthalate	Esters	85-68-7	
Butylamine	Amines, alkyl	109-73-9	Flammable w/toxic products
Butyric acid	Acidic compounds, organic	107-92-6	Combustible
Carbon disulfide	Sulfides and mercaptans	75-15-0	Flammable w/toxic products
Carbon tetrachloride	Halides, alkyl	56-23-5	Potential carcinogen
Chloral	Aldehydes, Aliphatics, halogenated	75-87-6	Combustible w/toxic products Corrosive Potential carcinogen
Chloroacetaldehyde	Aldehydes, Aliphatics, halogenated	107-20-0	Combustible w/toxic products Polymerizable
Chlorobenzene	Aromatics, halogenated	108-90-7	Flammable w/toxic products

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Chlorodibromomethane	Aliphatics, halogenated	124-48-1	
Chloroethane	Aliphatics, halogenated	75-00-3	Flammable w/toxic products
2-Chloroethyl vinyl ether	Ethers, Aliphatics, halogenated	110-75-8	Flammable w/toxic products
Chloroform	Halides, alkyl	67-66-3	Potential carcinogen
Chloromethyl methyl ether	Ethers, Aliphatics, halogenated	107-30-2	Flammable w/toxic products Potential carcinogen Poison
2-Chlorophenol	Phenols and cresols, Aromatics, halogenated	95-57-8	Combustible w/toxic products
4-Chlorophenyl phenyl ether	Ethers, Aromatics, halogenated	7005-72-3	Combustible w/toxic products
3-Chloropropionitrile	Cyanides and nitriles	542-76-7	Combustible w/toxic products
Chlorosulfonic acid	Acidic compounds, inorganic	7790-94-5	Corrosive Reactive
Creosote	Phenols and cresols, Aromatics	8001-58-9	Combustible Potential carcinogen
Cresol	Phenols and cresols, Aromatics	1319-77-3	Combustible
Crotonaldehyde	Aldehydes, Olefins	4170-30-3 123-73-9	Flammable
Cumene	Aromatics	98-82-8	Combustible
Cyanogen chloride	Cyanides and nitriles	506-77-4	Poison
Cyclohexane	Aliphatics	110-82-7	Flammable
Cyclohexanone	Ketones	108-94-1	Combustible
2,4-D esters	Esters	94-11-1	Combustible w/toxic products
Diazinon	Organophosphates	333-41-5	Combustible w/toxic products

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
1,2-Dibromo-3-chloropropane (Note 2)	Aliphatics, halogenated	96-12-8	Combustible w/toxic products Potential carcinogen
Di-n-butylphthalate	Esters	84-74-2	
Dichlorobenzene (all isomers)	Aromatics, halogenated	25321-22-6	Combustible w/toxic products
o-Dichlorobenzene	Aromatics, halogenated	95-50-1	Combustible w/toxic products
m-Dichlorobenzene	Aromatics, halogenated	541-73-1	Combustible w/toxic products
Dichlorobromomethane	Aliphatics, halogenated	75-27-4	Combustible w/toxic products
1,4-Dichloro-2-butene	Aliphatics, halogenated	764-41-0	Flammable w/toxic products
1,1-Dichloroethane	Aliphatics, halogenated	75-34-3	Flammable w/toxic products
1,2-trans-Dichloroethylene	Aliphatics, halogenated	156-60-5	Flammable w/toxic products
Dichloropropane (all isomers)	Aliphatics, halogenated	26638-19-7	Flammable w/toxic products
1,3-Dichloropropene	Aliphatics, halogenated	542-75-6	Flammable w/toxic products
Dichloropropene (all isomers)	Aliphatics, halogenated	26952-23-8	Flammable w/toxic products
Dichloropropene-Dichloropropane mixture	Aliphatics, halogenated	8003-19-8	Flammable w/toxic products
2,2-Dichloropropionic acid	Acidic compounds, organic, Aliphatics, halogenated	75-99-0	Corrosive
Dichlorvos	Organophosphates	62-73-7	Poison
Diethylamine	Amines, alkyl	109-89-7	Flammable w/toxic products Corrosive

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Diethylarsine (Note 2)	Organometallics, Heavy metals	692-42-2	Flammable w/toxic products
N,N'-Diethylhydrazine	Hydrazines and hydrazides	1615-80-1	Combustible w/toxic products Potential carcinogen
O,O-Diethyl-S-methyl dithiophosphate (Note 2)	Organophosphates	3288-58-2	
Diethyl-p-nitrophenyl phosphate	Organophosphates, Nitro compounds	311-45-5	
Diethyl phthalate	Esters, Aromatics	84-66-2	
O,O-Diethyl O-pyrazinyl phosphorothioate	Organophosphates	297-97-2	
Dihydrosafrole (Note 2)	Aromatics, Ethers	94-58-6	Potential carcinogen
Diisopropyl fluorophosphate	Organophosphates	55-91-4	Corrosive
alpha,alpha-Dimethylbenzylhydroperoxide	Peroxides, Aromatics	80-15-9	Explosive Combustible
Dimethyl carbamoyl chloride (Note 2)	Halides, alkyl	79-44-7	Combustible w/toxic products Reactive Potential carcinogen
alpha,alpha-Dimethylphenethylamine (Note 1)	Amines, aryl	122-09-8	
Dimethyl phthalate	Esters	131-11-3	Combustible
Dimethyl sulfate	Sulfates	77-78-1	Combustible w/toxic products Corrosive Potential carcinogen
1,1-Dimethylhydrazine	Hydrazines and hydrazides	57-14-7	Flammable w/toxic products Corrosive Potential carcinogen Poison

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
1,2-Dimethylhydrazine	Hydrazines and hydrazides	540-73-8	Flammable w/toxic products Corrosive Potential carcinogen
Di-n-octylphthalate	Esters	117-84-0	
1,4-Dioxane	Ethers	123-91-1	Flammable Potential carcinogen
Dipropylamine	Amines, alkyl	142-84-7	Flammable w/toxic products
Dodecylbenzenesulfonic acid	Acids, organic, Aromatics	27176-87-0	Combustible w/toxic products
Endrin aldehyde (Note 2)	Aldehydes	930-55-2	
Epichlorohydrin	Epoxides, Aliphatics, halogenated	106-89-8	Flammable w/toxic products
Ethion	Organophosphates	563-12-2	Poison
Ethyl acetate	Esters	141-78-6	Flammable
Ethyl acrylate	Esters, Olefins	140-88-5	Flammable Polymerizable
Ethyl cyanide	Cyanides and nitriles	107-12-0	Flammable w/toxic products
Ethyl-4,4'-dichlorobenzilate (Note 1)	Esters, Aliphatics, halogenated	510-15-6	
Ethyl ether	Ethers	60-29-7	Explosive, upon standing Flammable
Ethyl methacrylate	Esters, Olefins	97-63-2	Flammable Polymerizable
Ethyl methanesulfonate (Note 2)	Esters	62-50-0	
Ethylbenzene	Aromatics	100-41-4	Flammable
Ethylene dibromide	Aliphatics, halogenated	106-93-4	Potential carcinogen
Ethylene dichloride	Aliphatics, halogenated	107-06-2	Flammable w/toxic products Potential carcinogen

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Ethylene oxide	Oxides, alkylene	75-21-8	Flammable Corrosive
Ethylenediamine	Amines, alkyl	107-15-3	Flammable w/toxic products Corrosive
Ethylenimine	Amines, alkyl	151-56-4	Flammable w/toxic products Poison
Formic acid	Acidic compounds, organic	64-18-6	Combustible
Furan	Ethers, Aromatics	110-00-9	Flammable
Furfural	Aldehydes, Olefins	98-01-1	Combustible
Glycidaldehyde (Note 2)	Aldehydes	765-34-4	Flammable Potential carcinogen
Hexachlorobutadiene	Aliphatics, halogenated, Olefins	87-68-3	
Hexachlorocyclopentadiene	Aliphatics, halogenated, Olefins	77-47-4	
Hexachloropropene (Note 2)	Aliphatics, halogenated, Olefins	1888-71-7	
Hexaethyl tetraphosphate	Organophosphates	757-58-4	Poison
Hydrazine	Hydrazines and hydrazides	302-01-2	Flammable w/toxic products Corrosive Potential carcinogen Poison
Hydrochloric acid	Acidic compounds, inorganic	7647-01-0	Corrosive Reactive
Hydrocyanic acid	Cyanides and nitriles, Acidic compounds, inorganic	74-90-8	Flammable w/toxic products Poison

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Hydrofluoric acid	Acidic compounds, inorganic	7664-39-3	Corrosive Reactive
Isobutyl alcohol	Alcohols and glycols	78-83-1	Flammable
Isophorone	Ketones	78-59-1	Combustible
Isoprene	Olefins	78-79-5	Flammable Polymerizable
Isosafrole (Note 2)	Aromatics, Ethers	120-58-1	Potential carcinogen
Lead fluoborate (in aqueous solution)	Heavy metals, Halides, inorganic	13814-96-5	
Malathion	Organophosphates	121-75-5	
Mercury	Heavy metals	7439-97-6	
Methacrylonitrile	Cyanides and nitriles	126-98-7	Flammable w/toxic products Polymerizable
Methanol	Alcohols and glycols	67-56-1	Flammable
Methapyriline (Note 1)	Amines, aryl	91-80-5	
Methyl chlorocarbonate	Esters, Aliphatics, halogenated	79-22-1	Flammable w/toxic products
Methyl chloroform	Halides, alkyl	71-55-6	Combustible w/toxic products
Methyl ethyl ketone	Ketones	78-93-3	Flammable
Methyl hydrazine	Hydrazines and hydrazides	60-34-4	Flammable w/toxic products Poison
Methyl iodide	Halides, alkyl	74-88-4	Potential carcinogen
Methyl isobutyl ketone	Ketones	108-10-1	Flammable
Methyl isocyanate	Cyanates	624-83-9	Flammable w/toxic products
Methyl methacrylate	Esters, Olefins	80-62-6	Flammable Polymerizable

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Methylene bromide	Halides, alkyl	74-95-3	
Methylene chloride	Halides, alkyl	75-09-2	Combustible w/toxic products
Mevinphos	Organophosphates	7786-34-7	Combustible w/toxic products Poison
Monoethylamine	Amines, alkyl	75-04-7	Flammable w/toxic products Corrosive
Naphthenic acid	Acidic compounds, organic	1338-24-5	Combustible
Nickel carbonyl	Organometallics, Heavy metals	13463-39-3	Flammable w/toxic products Reactive Potential carcinogen
Nicotine and salts	Amines, aryl	54-11-5	Combustible w/toxic products Poison
Nitric acid	Acidic compounds, inorganic	7697-37-2	Corrosive Reactive Oxidizer
Nitrobenzene	Nitro compounds, Aromatics	98-95-3	Combustible w/toxic products Poison
Nitrogen dioxide	Acidic compounds, inorganic	10102-44-0	Corrosive Oxidizer Poison
2-Nitropropane	Nitro compounds	79-46-9	Flammable w/toxic products
N-Nitrosodiethanolamine	Nitroso compounds	1116-54-7	Combustible w/toxic products Potential carcinogen
N-Nitrosodiethylamine	Nitroso compounds	55-18-5	Combustible w/toxic products Potential carcinogen

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
N-Nitrosodimethylamine	Nitroso compounds	62-75-9	Flammable w/toxic products Potential carcinogen
N-Nitrosodi-n-propylamine	Nitroso compounds	621-64-7	Combustible w/toxic products Potential carcinogen
N-Nitroso-N-methylurea (Note 1)	Nitroso compounds	684-93-5	Combustible w/toxic products Potential carcinogen
N-Nitrosomethylvinylamine	Nitroso compounds	4549-40-0	Flammable w/toxic products Potential carcinogen
N-Nitrosopyrrolidine	Nitroso compounds,	930-55-2	Combustible w/toxic products Potential carcinogen
Octamethylpyrophosphoramide	Amides, anilides and, imides, Organophosphates	152-16-9	
Paraldehyde	Ethers	123-63-7	Flammable
Parathion	Organophosphates	56-38-2	Poison
Pentachloroethane	Aliphatics, halogenated	76-01-7	Combustible w/toxic products
1,3-Pentadiene	Olefins	504-60-9	Flammable
Phosphoric acid	Acidic compounds, inorganic	7664-38-2	Corrosive
Phosphorus oxychloride	Phosphorous and compounds, Halides, inorganic	10025-87-3	Corrosive Reactive
Phosphorus trichloride	Phosphorous and compounds, Halides, inorganic	7719-12-2	Corrosive Reactive
2-Picoline	Amines, aryl	109-06-8	Combustible w/toxic products
Polychlorinated biphenyls	Aromatics, halogenated	1336-36-3	Potential carcinogen

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Propargite	Sulfites, Aromatics	2312-35-8	Flammable w/toxic products
Propargyl alcohol	Alcohols and glycols	107-19-7	Flammable Poison
Propionic acid	Acidic compounds, organic	79-09-4	Combustible
Propionic anhydride	Acidic compounds, organic	123-62-6	Combustible
n-Propylamine	Amines, alkyl	107-10-8	Flammable w/toxic products
Propylene dichloride	Aliphatics, halogenated	78-87-5	Flammable w/toxic products
Propylene oxide	Oxides, alkylene	75-56-9	Flammable Corrosive
1,2-Propylenimine	Amines, alkyl	75-55-8	Flammable w/toxic products Potential carcinogen
Pyridine	Amines, aryl	110-86-1	Flammable w/toxic products
Quinoline	Amines, aryl	91-22-5	Combustible
Safrole	Aromatics, Ethers	94-59-7	Combustible Potential carcinogen
Selenious acid	Acidic compounds, inorganic	7783-00-8	
Sodium hypochlorite (in aqueous solution)	Basic compounds	10022-70-5 7681-52-9	
Styrene	Aromatics, Olefins	100-42-5	Flammable Polymerizable
Sulfur monochloride	Halides, inorganic	12771-08-3	Corrosive Reactive
Sulfuric acid	Acidic compounds, inorganic	7664-93-9	Corrosive Reactive
2,4,5-T amines	Amines, aryl, Aromatics, halogenated	2008-46-0	Combustible w/toxic products

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
2,4,5-T esters	Esters, Aromatics, halogenated	N.A.	
1,1,1,2-Tetrachloroethane	Aliphatics, halogenated	630-20-6	
1,1,2,2-Tetrachloroethane	Aliphatics, halogenated	79-34-5	
Tetrachloroethylene	Aliphatics, halogenated, Olefins	127-18-4	
Tetraethyldithiopyrophosphate	Organophosphates	3689-24-5	Poison
Tetraethyl lead	Organometallics, Heavy metals	78-00-2	Combustible w/toxic products Poison
Tetraethyl pyrophosphate	Organophosphates	107-49-3	Combustible w/toxic products Poison
Tetrahydrofuran	Ethers	109-99-9	Flammable
Tetranitromethane	Nitro compounds	509-14-8	Explosive Oxidizer
Thiophenol	Phenols and cresols	108-98-5	
Toluene	Aromatics	108-88-3	Flammable
Toluene diisocyanate	Cyanates, Aromatics	584-84-9	Combustible w/toxic products Poison
2,4,5-TP acid esters	Esters, Aromatics, halogenated	N.A.	Combustible w/toxic products
1,2,4-Trichlorobenzene	Aromatics, halogenated	120-82-1	Combustible w/toxic products
1,1,2-Trichloroethane	Aliphatics, halogenated	79-00-5	Combustible w/toxic products
Trichloroethylene	Aliphatics, halogenated	79-01-6	(Flammable w/toxic products)

TABLE 2A. LIQUIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Trichloromonofluoromethane	Aliphatics, halogenated	75-69-4	
Triethylamine	Amines, alkyl	121-44-8	Flammable w/toxic products Corrosive
Vinyl acetate	Esters, Olefins	108-05-4	Flammable Polymerizable
Vinylidene chloride	Aliphatics, halogenated	75-35-4	Flammable w/toxic products Polymerizable Potential carcinogen
Xylene	Aromatics	1330-20-7	Flammable
Xylenol	Phenols and cresols	1300-71-6	Combustible

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Acenaphthene	Aromatics	83-32-9	Combustible
Acenaphthylene	Aromatics	208-96-8	Combustible
2-Acetylaminofluorene	Amines, aryl	53-96-3	Potential carcinogen
1-Acetyl-2-thiourea	Ureas	591-08-2	
Acrylamide	Amides, anilides and imides	79-06-1	Polymerizable
Adipic acid	Acidic compounds, organic	124-04-9	
Aldicarb	Esters	116-06-3	
Aldrin	Aromatics, halogenated	309-00-2	Combustible w/toxic products Potential carcinogen Poison
Aluminum phosphide	Phosphorous and compounds	20859-73-8	Flammable w/toxic products Reactive
Aluminum sulfate	Sulfates	10043-01-3	
5-(Aminomethyl)-3-isoxazolol	Amine, alkyl	2763-96-4	
Amitrole	Azo compounds	61-82-5	Potential carcinogen
Ammonium acetate	Organic ammonium compounds	631-61-8	
Ammonium benzoate	Organic ammonium compounds	1863-63-4	Combustible w/toxic products
Ammonium bicarbonate	Organic ammonium compounds	1066-33-7	
Ammonium bichromate	Chromates	7789-09-5	Corrosive Oxidizer Flammable
Ammonium bifluoride	Halides, inorganic	1341-49-7	Corrosive
Ammonium bisulfite	Sulfites	10192-30-0	

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Ammonium carbamate	Organic ammonium compounds	1111-78-0	
Ammonium carbonate	Organic ammonium compounds	10361-29-2	
Ammonium chloride	Halides, inorganic	12125-02-9	
Ammonium chromate	Chromates	7788-98-9	
Ammonium citrate, dibasic	Organic ammonium compounds	3012-65-5	
Ammonium fluoborate	Organic ammonium compounds	13826-83-0	Corrosive
Ammonium fluoride	Halides, inorganic	12125-01-8	Corrosive
Ammonium oxalate	Organic ammonium compounds	6009-70-7 5972-73-6 14258-49-2	
Ammonium picrate	Nitro compounds	131-74-8	Flammable w/toxic products Explosive
Ammonium silicofluoride	Halides, inorganic	16919-19-0	Corrosive
Ammonium sulfamate	Sulfones, sulfoxides, and sulfonates	7773-06-0	
Ammonium sulfite	Sulfites	10196-04-0	Combustible w/toxic products
Ammonium tartrate	Organic ammonium compounds	3164-29-2 14307-43-8	
Ammonium thiocyanate	Cyanates	1762-95-4	Combustible w/toxic products
Ammonium thiosulfate	Sulfates	7783-18-8	
Ammonium vanadate	Heavy metals	7803-55-6	
Anthracene	Aromatics	120-12-7	Combustible
Antimony	Heavy metals	7440-36-0	Combustible w/toxic products
Antimony potassium tartrate	Organometallics Heavy metals	28300-74-5	

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Antimony tribromide	Halides, inorganic Heavy metals	7789-61-9	Corrosive Reactive
Antimony trichloride	Halides, inorganic Heavy metals	10025-91-9	Corrosive Reactive
Antimony trifluoride	Halides, inorganic Heavy metals	7783-56-4	Corrosive Reactive
Antimony trioxide	Oxides Heavy metals	1309-64-4	
Arsenic	Heavy metals	7440-38-2	Combustible w/toxic products Potential carcinogen Poison
Arsenic acid	Acidic compounds, inorganic, Heavy metals	1327-52-2 7778-39-4	Corrosive Poison
Arsenic disulfide	Sulfides and mercaptans Heavy metals	1303-32-8	Combustible w/toxic products Poison
Arsenic pentoxide	Oxides Heavy metals	1303-28-2	Corrosive Poison
Arsenic trioxide	Oxides Heavy metals	1327-53-3	Corrosive Poison
Arsenic trisulfide	Sulfides and mercaptans Heavy metals	1303-33-9	Combustible w/toxic products Poison
Asbestos	(See asbestos)	1332-21-4	Potential carcinogen
Auramine	Amines, aryl	492-80-8	Potential carcinogen
Azaserine	Azo compounds	115-02-6	Potential carcinogen
Barium cyanide	Cyanides and nitriles	542-62-1	Poison
3,4-Benzacridine	Aromatics	225-51-4	

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
1,2-Benzanthracene	Aromatics	56-55-3	Potential carcinogen
alpha-Benzenehexachloride	Aliphatics, halogenated	319-84-6	Potential carcinogen
beta-Benzenehexachloride	Aliphatics, halogenated	319-85-7	Potential carcinogen
delta-Benzenehexachloride	Aliphatics, halogenated	319-86-8	Potential carcinogen
Benzidine	Amines, aryl	92-87-5	Combustible w/toxic products Potential carcinogen Poison
Benzo[b]fluoranthene	Aromatics	205-99-2	Potential carcinogen
Benzo[k]fluoranthene	Aromatics	207-08-9	Potential carcinogen
Benzo[ghi]perylene	Aromatics	191-24-2	
Benzoic acid	Acidic compounds, organic	65-85-0	Combustible
Benzo[a]pyrene	Aromatics	50-32-8	Potential carcinogen
p-Benzoquinone	Ketones	106-51-4	Combustible
Beryllium chloride	Halides, inorganic Heavy metals	7787-47-5	Poison
Beryllium	Heavy metals	7440-41-7	Flammable w/toxic products Potential carcinogen
Beryllium fluoride	Halides, inorganic Heavy metals	7787-49-7	Poison
Beryllium nitrate	Nitrates and nitrites Heavy metals	7787-55-5 13597-99-4	Oxidizer

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Brucine	(See strychnine and salts)	357-57-3	Combustible w/toxic products Poison
Cacodylic acid	Organometallics Heavy metals	75-60-5	Poison
Cadmium	Heavy metals	7440-43-9	Flammable w/toxic products Potential carcinogen
Cadmium acetate	Organometallics Heavy metals	543-90-8	Poison
Cadmium bromide	Halides, inorganic Heavy metals	7789-42-6	Poison
Cadmium chloride	Halides, inorganic Heavy metals	10108-64-2	Potential carcinogen
Calcium arsenate	Heavy metals	7778-44-1	Poison
Calcium arsenite	Heavy metals	52740-16-6	Poison
Calcium carbide	Organometallics	75-20-7	Flammable Reactive
Calcium chromate	Chromate	13765-19-0	Potential carcinogen
Calcium cyanide	Cyanides and nitriles	592-01-8	Reactive Poison
Calcium dodecylbenzene sulfonate	Sulfones, sulfoxides, and sulfonates	26264-06-2	
Calcium hypochlorite	Halides, inorganic	7778-54-3	Oxidizer
Captan	Acidic compounds, organic, Amides, anilides, and imides	133-06-2	Combustible w/toxic products
Carbaryl	Esters	63-25-2	Combustible w/toxic products
Carbofuran	Esters	1563-66-2	Combustible w/toxic products Poison

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Chlorambucil	Aromatics, halogenated Amines, aryl	305-03-3	Potential carcinogen
Chlordane	Aliphatics, halogenated Olefins	57-74-9	Combustible w/toxic products Potential carcinogen
Chlornaphazine (note1)	Amines, aryl	494-03-1	Potential carcinogen
p-Chloroaniline	Aromatics, halogenated Amines, aryl	106-47-8	
p-Chloro-m-cresol	Phenols and cresols Aromatics, halogenated	59-50-7	Combustible w/toxic products
2-Chloronaphthalene	Aromatics, halogenated	91-58-7	Combustible w/toxic products
1-(o-Chlorophenyl)-thiourea	Aromatics, halogenated Ureas	5344-82-1	
4-Chloro-o-toluidine, hydrochloride	Aromatics, halogenated Amines, aryl	3165-93-3	Poison
Chlorpyrifos	Organophosphates Aromatics, halogenated	2921-88-2	Combustible w/toxic products
Chromic acetate	Organometallics	1066-30-4	
Chromic acid	Acidic compounds, inorganic	11115-74-5	Corrosive Oxidizer Potential carcinogen
Chromic sulfate	Sulfates	10101-53-8	
Chromium	Heavy metals	7440-47-3	Flammable w/toxic products
Chromous chloride	Halides, inorganic	10049-05-5	Reactive
Chrysene	Aromatics	218-01-9	Combustible
Cobaltous bromide	Halides, inorganic Heavy metals	7789-43-7	
Cobaltous formate	Organometallics Heavy metals	544-18-3	

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Cobaltous sulfamate	Heavy metals	14017-41-5	
Copper	Heavy metals	7440-50-8	
Copper cyanide	Cyanides and nitriles Heavy metals	544-92-3	Poison
Coumaphos	Organophosphates Aromatics, halogenated	56-72-4	Combustible w/toxic products Poison
Cupric acetate	Organometallics Heavy metals	142-71-2	
Cupric acetoarsenite	Organometallics Heavy metals	12002-03-8	Poison
Cupric chloride	Halides, inorganic Heavy metals	7447-39-4	
Cupric nitrate	Nitrates and nitriles Heavy metals	3251-23-8	
Cupric oxalate	Organometallics Heavy metals	814-91-5	
Cupric sulfate	Sulfates Heavy metals	7758-98-7	
Cupric sulfate ammoniated	Sulfates Heavy metals	10380-29-7	
Cupric tartrate	Organometallics Heavy metals	815-82-7	
Cyanides (soluble salts and complexes)	Cyanides and nitriles	57-12-5	Poison
Cyanogen bromide	Cyanides and nitriles	506-68-3	Poison
Cyclophosphamide	Organophosphates Amides, anilides and imides	50-18-0	Potential carcinogen
2,4-D acid	Acidic compounds, organic, Aromatics, halogenated	94-75-7	Combustible w/toxic products
Daunonycin	Aromatics Ketones	20830-81-3	Potential carcinogen

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
DDD	Aromatics, halogenated	72-54-8	Combustible w/toxic products Potential carcinogen
DDE	Aromatics, halogenated	72-55-9	Combustible w/toxic products Potential carcinogen
DDT	Aromatics, halogenated	50-29-3	Combustible w/toxic products Potential carcinogen
Diallate	Esters	2303-16-4	
Dibenzo[a,h]anthracene	Aromatics	53-70-3	Potential carcinogen
Dibenzo[a,i]pyrene	Aromatics	189-55-9	Potential carcinogen
Dicamba	Acidic compounds, organic, Aromatics, halogenated	1918-00-9	Combustible w/toxic products
Dichlobenil	Cyanides and nitriles Aromatics, halogenated	1194-65-6	Combustible w/toxic products
Dichlone	Aromatics, halogenated	117-80-6	Combustible w/toxic products
p-Dichlorobenzene	Aromatics, halogenated	106-46-7	Combustible w/toxic products
3,3'-Dichlorobenzidine	Aromatics, halogenated Amines, aryl	91-94-1	Combustible w/toxic products Potential carcinogen
2,4-Dichlorophenol	Phenols and cresols Aromatics, halogenated	120-83-2	Combustible w/toxic products
2,6-Dichlorophenol	Phenols and cresols Aromatics, halogenated	87-65-0	Combustible w/toxic products
Dieldrin	Epoxides Aromatics, halogenated	60-57-1	Potential carcinogen

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Diethylstilbestrol	Aromatics Ketones	56-53-1	Potential carcinogen
Dimethoate	Organophosphates	60-51-5	Flammable w/toxic products
3,3'-Dimethoxybenzidine	Amines, aryl	119-90-4	Potential carcinogen
Dimethylaminoazobenzene	Azo compounds Amines, aryl	60-11-7	Potential carcinogen
7,12-Dimethylbenz[a]-anthracene	Aromatics	57-97-6	
3,3'-Dimethylbenzidine	Amines, aryl	119-93-7	Potential carcinogen
2,4-Dimethylphenol	Phenols and cresols	105-67-9	Combustible
Dinitrobenzene (mixed)	Nitro compounds Aromatics	25154-54-5	Poison
4,6-Dinitro-o-cresol	Nitro compounds Phenols and cresols	534-52-1	Combustible w/toxic products
4,6-Dinitro-o-cyclohexylphenol	Nitro compounds Phenols and cresols	131-89-5	Combustible w/toxic products
Dinitrophenol	Nitro compounds Phenols and cresols	25550-58-7	Combustible w/toxic products Poison
2,4-Dinitrophenol	Nitro compounds Phenols and cresols	51-28-5	Combustible w/toxic products Poison
Dinitrotoluene	Nitro compounds Aromatics	25321-14-6	
2,4-Dinitrotoluene	Nitro compounds Aromatics	121-14-2	
2,6-Dinitrotoluene	Nitro compounds Aromatics	606-20-2	
Dinoseb	Nitro compounds Phenols and cresols	88-85-7	Flammable w/toxic products

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
1,2-Diphenylhydrazine	Hydrazines and Hydrazides	122-66-7	Combustible w/toxic products Potential carcinogen
Diquat	Aromatics, halogenated	85-00-7 2764-72-9	Combustible w/toxic products
Disulfoton	Organophosphates	298-04-4	Combustible w/toxic products Poison
2,4-Dithiobiuret	Amides, anilides, and imides	541-53-7	
Diuron	Ureas Aromatics, halogenated	330-54-1	Combustible w/toxic products
Endosulfan	Aromatics, halogenated Sulfones, sulfoxides, and sulfonates	115-29-7	Combustible w/toxic products Poison
alpha-Endosulfan	Aromatics, halogenated Sulfones, sulfoxides, and sulfonates	959-98-8	Poison
beta-Endosulfan	Aromatics, halogenated Sulfones, sulfoxides and sulfonates	33213-65-9	Poison
Endosulfan sulfate	Aromatics, halogenated Sulfones, sulfoxides and sulfonates	1031-07-8	Combustible w/toxic products
Endothall	Acidic compounds, organic	145-73-3	
Endrin	Epoxides Aromatics, halogenated	72-20-8	Poison
Epinephrene	Amines, aryl	51-43-4	
Ethyl carbamate	Esters	51-79-6	Potential carcinogen
Ethylenebis(dithiocarbamic acid)	Acidic compounds, organic	111-54-6	

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Ethylenediamine tetraacetic acid	Amines, alkyl Acidic compounds, organic	60-00-4	Combustible w/toxic products
Ethylenethiourea	Ureas	96-45-7	Potential carcinogen
Famphur	Organophosphates Amides, anilides and imides	52-85-7	
Ferric ammonium citrate	Organometallics	1185-57-5	
Ferric ammonium oxalate	Organometallics	2944-67-4 55488-87-4	
Ferric chloride	Halides, inorganic	7705-08-0	
Ferric fluoride	Halides, inorganic	7783-50-8	
Ferric nitrate	Nitrates and nitrites	10421-48-4	Oxidizer
Ferric sulfate	Sulfates	10028-22-5	
Ferrous ammonium sulfate	Sulfates	10045-89-3	
Ferrous chloride	Halides, inorganic	7758-94-3	
Ferrous sulfate	Sulfates	7720-78-7 7782-63-0	
Fluoranthene	Aromatics	206-44-0	
Fluorene	Aromatics	86-73-7	
Fluoroacetamide	Amides, anilides, and imides	640-19-7	
Fumaric acid	Acidic compounds, organic	110-17-8	Combustible
Guthion	Aromatics Organophosphates	86-50-0	Poison
Heptachlor	Aliphatics, halogenated Olefins	76-44-8	Potential carcinogen
Heptachlor epoxide	Aliphatics, halogenated Epoxides	1024-57-3	Potential carcinogen

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Hexachlorobenzene	Aromatics, halogenated	118-74-1	Potential carcinogen
Hexachloroethane	Aliphatics, halogenated	67-72-1	
Hexachlorohexahydro-endo,endo-dimethanonaphthalene	Aromatics, halogenated	465-73-6	Poison
Hexachlorophene	Aromatics, halogenated	70-30-4	
Indeno(1,2,3-cd)pyrene	Aromatics	193-39-5	Potential carcinogen
Iron dextran	Organometallics	9004-66-4	Potential carcinogen
Isopropanolamine dodecylbenzenesulfonate	Sulfones, sulfoxides and sulfonates	42504-46-1	Combustible w/toxic products
Kelthane	Aromatics, halogenated	115-32-2	Combustible w/toxic products
Kepone	Aliphatics, halogenated Ketones	143-50-0	Combustible w/toxic products Potential carcinogen
Lasiocarpine	Acidic compounds, organic	303-34-4	Potential carcinogen
Lead	Heavy metals	7439-92-1	
Lead acetate	Organometallics Heavy metals	301-04-2	Potential carcinogen
Lead arsenate	Heavy metals	7784-40-9 3687-31-8 7645-25-2 10102-48-4	Poison
Lead chloride	Halides, inorganic Heavy metals	7758-95-4	
Lead fluoride	Halides, inorganic Heavy metals	7783-46-2	
Lead iodide	Halides, inorganic Heavy metals	10101-63-0	

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Lead nitrate	Nitrates and nitrites Heavy metals	10099-74-8	Oxidizer
Lead phosphate	Phosphates and phosphonates Heavy metals	7446-27-7	Potential carcinogen
Lead stearate	Organometallics Heavy metals	7428-48-0 1072-35-1 56189-09-4	
Lead subacetate	Organometallics Heavy metals	1335-32-6	Potential Carcinogen
Lead sulfate	Sulfates Heavy metals	7446-14-2 15739-80-7	
Lead sulfide	Sulfides and mercaptans Heavy metals	1314-87-0	
Lead thiocyanate	Cyanates Heavy metals	592-87-0	
Lindane	Aliphatics, halogenated	58-89-9	Potential carcinogen
Lithium chromate	Chromates	14307-35-8	
Maleic acid	Acidic compounds, organic	110-16-7	
Maleic anhydride	Acidic compounds, organic	108-31-6	Combustible
Maleic hydrazide	Hydrazines and hydrazides	123-33-1	Combustible w/toxic products
Malononitrile	Cyanides and nitriles	109-77-3	Combustible w/toxic products
Melphalan	Aromatics, halogenated Amines, aryl	148-82-3	Potential carcinogen
Mercaptodimethur	Sulfides and mercaptans	2032-65-7	
Mercuric cyanide	Cyanides and nitriles Heavy metals	592-04-1	Poison
Mercuric nitrate	Nitrates and nitrites Heavy metals	10045-94-0	Oxidizer

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Mercuric sulfate	Sulfates Heavy metals	7783-35-9	Poison
Mercuric thiocyanate	Cyanates Heavy metals	592-85-8	Poison
Mercurous nitrate	Nitrates and nitrites Heavy metals	7782-86-7 10415-75-5	Oxidizer
Mercury fulminate	Cyanides and nitriles	628-86-4	Explosive
Methomyl	Amides, anilides and imides	16752-77-5	
Methyl bromide	Halides, alkyl	74-83-9	Combustible w/toxic products Poison
Methoxychlor	Aromatics, halogenated	72-43-5	
3-Methylcholanthrene	Aromatics	56-49-5	Potential carcinogen
4,4'-Methylenebis-(2-chloroaniline)	Aromatics, halogenated Amines, aryl	101-14-4	Potential carcinogen
Methyl parathion	Organophosphates	298-00-0	Combustible w/toxic products Poison
N-Methyl-N'-nitro-N-nitrosoguanidine	Nitro compounds Nitroso compounds	70-25-7	Flammable w/toxic products Potential carcinogen
Methylthiouracil	Amines, akyl	56-04-2	Potential carcinogen
Mexacarbate	Esters	315-18-4	Combustible w/toxic iproducts Poison
Mitomycin C	(See mitomycin)	50-07-7	Potential carcinogen
Naled	Aliphatics, halogenated Organophosphates	300-76-5	Combustible w/toxic products
Naphthalene	Aromatics	91-20-3	Combustible

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
1,4-Naphthoquinone	Aromatics	130-15-4	
1-Naphthylamine	Amines, aryl	134-32-7	
2-Naphthylamine	Amines, aryl	91-59-8	Potential carcinogen
alpha-Naphthylthiourea	Ureas	86-88-4	
Nickel	Heavy metals	7440-02-0	Flammable w/toxic products Potential carcinogen
Nickel ammonium sulfate	Sulfates Heavy metals	15699-18-0	
Nickel chloride	Halides, inorganic Heavy metals	37211-05-5 7718-54-9	
Nickel cyanide	Cyanides and nitriles Heavy metals	557-19-7	Poison
Nickel hydroxide	Basic compounds Heavy metals	12054-48-7	
Nickel nitrate	Nitrates and nitrites Heavy metals	14216-75-2	Oxidizer
Nickel sulfate	Sulfates Heavy metals	7786-81-4	
Nicotine salts	Amines, aryl	54-11-5	Combustible w/toxic products Poison
p-Nitroaniline	Nitro compounds Amines, aryl	100-01-6	Poison
Nitroglycerine	Nitro compounds	55-63-0	Flammable w/toxic products Explosive
Nitrophenol (mixed)	Nitro compounds Phenols and cresols	25154-55-6	Combustible w/toxic products
2-Nitrophenol	Nitro compounds Phenols and cresols	88-75-5	Combustible w/toxic products

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
4-Nitrophenol	Nitro compounds Phenols and cresols	100-02-7	Combustible w/toxic products
N-Nitrosodi-n-butylamine	Nitroso compounds	924-16-3	Combustible w/toxic products Potential carcinogen
N-Nitrosodiphenylamine	Nitroso compounds Amine, aryl	86-30-6	Potential carcinogen
N-Nitroso-N-ethylurea	Nitroso compounds	759-73-9	Potential carcinogen
N-Nitroso-N-methylurethane	Nitroso compounds	615-53-2	Combustible w/toxic products Potential carcinogen
N-Nitrosopiperidine	Nitroso compounds	100-75-4	Potential carcinogen
Nitrotoluene	Nitro compounds Aromatics	1321-12-6	Combustible w/toxic products
5-Nitro-o-toluidine	Nitro compounds Amines, aryl	99-55-8	
Osmium tetroxide	Oxides Heavy metals	20816-12-0	
Paraformaldehyde	Aldehydes	30525-89-4	Combustible
Pentachlorobenzene	Aromatics, halogenated	608-93-5	Combustible w/toxic products
Pentachloronitrobenzene	Nitro compounds Aromatics, halogenated	82-68-8	
Pentachlorophenol	Phenols and cresols Aromatics, halogenated	87-86-5	
Phenacetin	Aromatics Amides, anilides and imides	62-44-2	Potential carcinogen
Phenanthrene	Aromatics	85-01-8	

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Phenol	Phenols and cresols	108-95-2	Combustible Corrosive Poison
Phenyl dichloroarsine	Aromatics, halogenated Heavy metals	696-28-6	Poison
Phenylmercuric acetate	Organometallics Heavy metals	62-38-4	Combustible w/toxic products
N-Phenylthiourea	Ureas Aromatics	103-85-5	
Phorate	Organophosphates	298-02-2	
Phosphorus	Phosphorous and compounds	7723-14-0	Flammable w/toxic products Poison
Phosphorus pentasulfide	Phosphorous and compounds Sulfides and mercaptans	1314-80-3	Flammable w/toxic products Reactive
Phthalic anhydride	Aromatics	85-44-9	Corrosive
Potassium arsenate	Heavy metals	7784-41-0	Poison
Potassium arsenite	Heavy metals	10124-50-2	Poison
Potassium bichromate	Chromates	7778-50-9	Corrosive Oxidizer
Potassium chromate	Chromates	7789-00-6	
Potassium cyanide	Cyanides and nitriles	151-50-8	Poison
Potassium hydroxide	Basic compounds	1310-58-3	Corrosive
Potassium permanganate	Basic compounds	7722-64-7	Corrosive Oxidizer
Potassium silver cyanide	Cyanides and nitriles Heavy metals	506-61-6	
Pronamide	Aromatics, halogenated Amides,anilides, and imides	23950-58-5	
1,3-Propane sultone	Sulfones, sulfoxides, and sulfonates	1120-71-4	Potential carcinogen

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Pyrene	Aromatics	129-00-0	Combustible w/toxic products
Pyrethrins	Acidic compounds, organic	121-21-1 121-29-9	Combustible w/toxic products
4-Pyridinamine	Amines, aryl	504-24-5	Combustible w/toxic products
Reserpine	Aromatics	50-55-5	
Resorcinol	Aromatics	108-46-3	Combustible
Saccharin	Aromatics Sulfones, sulfoxides and sulfonates	81-07-2	Potential carcinogen
Selenium	Heavy metals	7782-49-2	Combustible w/toxic products
Selenium disulfide	Sulfides and mercaptans Heavy metals	7488-56-4	Reactive
Selenium oxide	Oxides Heavy metals	7446-08-4	Poison
Selenourea	Ureas Heavy metals	630-10-4	
Silver	Heavy metals	7440-22-4	
Silver cyanide	Cyanides and nitriles Heavy metals	506-64-9	Poison
Silver nitrate	Nitrates and nitrites Heavy metals	7761-88-8	Oxidizer
Sodium	Alkali metals	7440-23-5	Flammable Reactive Corrosive
Sodium arsenate	Heavy metals	7631-89-2	Poison
Sodium arsenite	Heavy metals	7784-46-5	Poison
Sodium azide	Azo compounds	26628-22-8	Explosive Combustible w/toxic products Poison

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Sodium bichromate	Chromates	10588-01-9	Corrosive Oxidizer
Sodium bifluoride	Halides, inorganic	1333-83-1	Corrosive
Sodium bisulfite	Sulfites	7631-90-5	
Sodium chromate	Chromates	7775-11-3	
Sodium cyanide	Cyanides and nitriles	143-33-9	Poison
Sodium dodecylbenzene sulfonate	Sulfones, sulfoxides and sulfonates	25155-30-0	
Sodium fluoride	Halides, inorganic	7681-49-4	
Sodium fluoroacetate	Organometallics	62-74-8	
Sodium hydrosulfide	Sulfides and mercaptans	16721-80-5	Flammable w/toxic products Reactive
Sodium hydroxide	Basic compounds	1310-73-2	Corrosive Reactive
Sodium methylate	Organometallics	124-41-4	Flammable w/toxic products Reactive
Sodium nitrite	Nitrates and nitrites	7632-00-0	Oxidizer
Sodium phosphate, dibasic	Phosphates and phosphonates	7558-79-4 10028-24-7 10039-32-4 10140-65-5	
Sodium phosphate, tribasic	Phosphates and phosphonates	7601-54-9 7785-84-4 10101-89-0 10361-89-4 7758-29-4 10124-56-8	
Sodium selenite	Heavy metals	10102-18-8 7782-82-3	Poison
Streptozotocin	(See streptozotocin)	18883-66-4	Potential carcinogen

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Strontium chromate	Chromates Heavy metals	7789-06-2	
Strontium sulfide	Sulfides and mercaptans Heavy metals	1314-96-1	Reactive
Strychnine and salts	(See strychnine and salts)	57-24-9	Poison
2,4,5-T acid	Aromatics, halogenated	93-76-5	
2,4,5-T salts	Aromatics, halogenated	13560-99-1	Combustible w/toxic products
1,2,4,5-Tetrachlorobenzene	Aromatics, halogenated	95-94-3	
2,3,7,8-tetrachlorodibenzo-p-dioxin	Aromatics, halogenated	1746-01-6	Combustible w/toxic products Potential carcinogen
2,3,4,6-Tetrachlorophenol	Phenols and cresols Aromatics, halogenated	58-90-2	Combustible w/toxic products
Thallium	Heavy metals	7440-28-0	
Thallium(I) acetate	Organometallics Heavy metals	563-68-8	
Thallium(I) carbonate	Organometallics Heavy metals	6533-73-9	
Thallium(I) chloride	Halides, inorganic Heavy metals	7791-12-0	Poison
Thallium(I) nitrate	Nitrates and nitrites Heavy metals	10102-45-1	Oxidizer
Thallium(III) oxide	Oxides Heavy metals	1314-32-5	Oxidizer
Thallium(I) selenide	Heavy metals	12039-52-0	
Thallium(I) sulfate	Sulfates Heavy metals	7446-18-6	Poison
Thioacetamide	Amides, anilides,and imides	62-55-5	Potential carcinogen

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Thiofanox	Sulfides and mercaptans Amides, anilides, and imides	39196-18-4	
Thiosemicarbazide	Azo compounds Ureas	79-19-6	
Thiourea	Ureas	62-56-6	Potential carcinogen
Thiram	Sulfides and mercaptans	137-26-8	Combustible w/toxic products
Toluenediamine	Amines, aryl	95-80-7	Potential carcinogen
o-Toluidine hydrochloride	Aromatics, halogenated Amines, aryl	636-21-5	Potential carcinogen
Toxaphene	Aliphatics, halogenated	8001-35-2	Combustible w/toxic products Potential carcinogen
2,4,5-TP acid	Acidic compounds, organic Aromatics, halogenated	93-72-1	
Trichlorfon	Aliphatics, halogenated Organophosphates	52-68-6	
Trichloromethanesulfenyl chloride	Aliphatics, halogenated	594-42-3	Poison
Trichlorophenol	Phenols and cresols Aromatics, halogenated	25167-82-2	
2,4,5-Trichlorophenol	Phenols and cresols Aromatics, halogenated	95-95-4	Combustible w/toxic products
2,4,6-Trichlorophenol	Phenols and cresols Aromatics, halogenated	88-06-2	Combustible w/toxic products
Triethanolamine dodecylbenzene sulfonate	Sulfones, sulfoxides, and sulfonates	27323-41-7	
sym-Trinitrobenzene	Nitro compounds Aromatics	99-35-4	Flammable w/toxic products Explosive

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Tris(2,3-dibromopropyl) phosphate	Phosphates and phosphonates	126-72-7	Potential carcinogen
Trypan blue	Azo compounds	72-57-1	Potential carcinogen
Uracil mustard	Aliphatics, halogenated Amines, alkyl	66-75-1	Potential carcinogen
Uranyl acetate	Organometallics Heavy metals	541-09-3	Radioactive
Uranyl nitrate	Nitrates and nitrites Heavy metals	10102-06-4 36478-76-9	Radioactive Oxidizer
Vanadium pentoxide	Oxides Heavy metals	1314-62-1	
Vanadyl sulfate	Sulfates Heavy metals	27774-13-6	
Warfarin	Aromatics	81-81-2	
Zinc	Heavy metals	7440-66-6	Combustible
Zinc acetate	Organometallics Heavy metals	557-34-6	
Zinc ammonium chloride	Halides, inorganic Heavy metals	52628-25-8 14639-97-5 14639-98-6	
Zinc borate	Heavy metals	1332-07-6	
Zinc bromide	Halides, inorganic Heavy metals	7699-45-8	
Zinc carbonate	Organometallics Heavy metals	3486-35-9	
Zinc chloride	Halides, inorganic Heavy metals	7646-85-7	
Zinc cyanide	Cyanides and nitriles Heavy metals	557-21-1	Poison
Zinc fluoride	Halides, inorganic Heavy metals	7783-49-5	

TABLE 3A. PARTICULATE SOLIDS RELEASED ON LAND

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Zinc formate	Organometallics Heavy metals	557-41-5	
Zinc hydrosulfite	Sulfites Heavy metals	7779-86-4	
Zinc nitrate	Nitrates and nitrites Heavy metals	7779-88-6	Oxidizer
Zinc phenolsulfonate	Phenols and cresols Heavy metals	127-82-2	Combustible w/toxic products
Zinc phosphide	Phosphorous and compounds Heavy metals	1314-84-7	Flammable w/toxic products Reactive Poison
Zinc silicofluoride	Halides, inorganic Heavy metals	16871-71-9	
Zinc sulfate	Sulfates and sulfites Heavy metals	7733-02-0	
Zirconium nitrate	Nitrates and nitrites Heavy metals	13746-89-9	Oxidizer
Zirconium potassium fluoride	Halides, inorganic Heavy metals	16923-95-8	
Zirconium sulfate	Sulfates Heavy metals	14644-61-2	
Zirconium tetrachloride	Halides, inorganic Heavy metals	10026-11-6	Corrosive Reactive

TABLE 4A. COMPRESSED GASES RELEASED INTO AIR

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Ammonia	Ammonia	7664-41-7	Corrosive
Carbon oxyfluoride	Halides, alkyl	353-50-4	Reactive
Chlorine	Halogens	7782-50-5	Oxidizer Poison
Cyanogen	Cyanides and nitriles	460-19-5	Flammable w/toxic products Poison
Dichlorodifluoromethane	Halides, alkyl	75-71-8	
Dimethylamine	Amines, alkyl	124-40-3	Flammable w/toxic products Corrosive
Fluorine	Halogens	7782-41-4	Corrosive Reactive Oxidizer Poison
Formaldehyde	Aldehydes	50-00-0	Flammable
Hydrogen sulfide	Sulfides and mercaptans	7783-06-4	Flammable w/toxic products Poison
Methyl bromide	Halides,alkyl	74-83-9	Combustible w/toxic products Poison
Methyl chloride	Halides, alkyl	74-87-3	Flammable w/toxic products
Methyl mercaptan	Sulfides and mercaptans	74-93-1	Flammable w/toxic products Corrosive
Monomethylamine	Amines, alkyl	74-89-5	Flammable w/toxic products Corrosive
Nitric oxide	Oxides	10102-43-9	Poison Oxidizer
Phosgene	Halides, organic	75-44-5	Combustible w/toxic products Poison

TABLE 4A. COMPRESSED GASES RELEASED INTO AIR

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Phosphine	Phosphorous and compounds	7803-51-2	Flammable w/toxic products Poison
Trimethylamine	Amines, alkyl	75-50-3	Flammable w/toxic products Corrosive
Vinyl chloride	Halides, alkyl	75-01-4	Flammable w/toxic products Polymerizable Potential carcinogen

Table 1B. Insoluble Sinkers in Water

Page 1 of 2

Applicable Countermeasures / Chemical Class	CONTAINMENT					DISPLACEMENT			TREATMENT												DISPOSAL			
	Dams, Berms and Dikes	Trenches	Curtain Barriers (1)	Stream Diversion	Synthetic Membrane Covers	Dredging (2)	Pumping	Dispersion/Dilution (3)	Activated Carbon	Synthetic Sorbents	Granular Media Filtration	Gravity Separation	Coagulation/Flocculation	Ion Exchange - Anionic	Ion Exchange - Cationic	Neutralize w/acid (4)	Neutralize w/base	Oxidation	Precipitation	Biological Treatment (7)	Incineration	Wet Air Oxidation	Landfill	Deep Well Injection
Acidic compounds, organic	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓					✓				✓		✓	✓
Aliphatics, halogenated	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						✓			✓		✓	✓
Amides, anilides and imides	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓									✓		✓	✓
Amines, alkyl	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓						✓			✓		✓	✓
Amines, aryl	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓						✓			✓		✓	✓
Aromatics	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓						✓			✓		✓	✓
Aromatics, halogenated	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓			✓		✓	✓
Asbestos	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓									✓		✓	✓
Azo compounds	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓									✓		✓	✓
Basic compounds	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓					✓		✓	✓
Chromates	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓					✓		✓		✓	✓
Cyanates	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓						✓		✓	✓
Cyanides and nitriles	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓(5)			✓	✓	✓	✓
Epoxides	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓						✓			✓		✓	✓
Esters	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓									✓		✓	✓
Ethers	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓									✓		✓	✓
Halides, alkyl	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓									✓		✓	✓
Halides, inorganic	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓		✓		✓		✓	✓
Heavy metals	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓		✓	✓
Ketones	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓									✓		✓	✓
Nitro compounds	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						✓			✓	✓	✓	✓
Nitroso compounds	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓									✓		✓	✓
Olefins	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓									✓		✓	✓
Organometallics	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓				✓		✓		✓	✓
Organophosphates	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓									✓		✓	✓

Table 1B. Insoluble Sinkers in Water (Continued)

Page 2 of 2

Applicable Countermeasures / Chemical Class	CONTAINMENT					DISPLACEMENT			TREATMENT												DISPOSAL			
	Dams, Berms and Dikes	Trenches	Curtain Barriers (1)	Stream Diversion	Synthetic Membrane Covers	Dredging (2)	Pumping	Dispersion/Dilution (3)	Activated Carbon	Synthetic Sorbents	Granular Media Filtration	Gravity Separation	Coagulation/Flocculation	Ion Exchange - Anionic	Ion Exchange - Cationic	Neutralize w/acid (4)	Neutralize w/base	Oxidation	Precipitation	Biological Treatment (7)	Incineration	Wet Air Oxidation	Landfill	Deep Well Injection
Oxides	✓	✓	✓			✓	✓	✓	✓		✓	✓			✓			✓			✓		✓	✓
Peroxides	✓	✓	✓			✓	✓	✓			✓	✓					✓				✓		✓	✓
Phenols and cresols	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓					(6) ✓		✓	✓	✓	✓	✓
Phosphorous and compounds	✓	✓	✓			✓	✓	✓			✓	✓		✓	✓						✓		✓	✓
Phosphates and phosphonates	✓	✓	✓			✓	✓	✓			✓	✓									✓		✓	✓
Strychnine and salts	✓	✓	✓			✓	✓	✓	✓		✓	✓									✓		✓	✓
Sulfates	✓	✓	✓			✓	✓	✓			✓	✓			✓						✓		✓	✓
Sulfides and mercaptans	✓	✓	✓			✓	✓	✓	✓		✓	✓		✓	✓			✓			✓	✓	✓	✓
Sulfites	✓	✓	✓			✓	✓	✓			✓	✓									✓		✓	✓
Sulfones, sulfoxides, & sulfonates	✓	✓	✓			✓	✓	✓	✓		✓	✓		✓							✓		✓	✓
Ureas	✓	✓	✓			✓	✓	✓			✓	✓									✓		✓	✓

(1) Use during dredging operations

(2) Mechanical dredging applicable to particulates only

(3) Reduce contaminant levels below toxic level through flow augmentation and mechanical mixing. Applicable to small spills in remote areas only!

(4) Treat with dilute and/or removable acids

(5) Treat with sodium hypochlorite or calcium hypochlorite

(6) Treat with hydrogen peroxide or ozone

(7) Potentially biodegradable

Table 2B. Soluble Sinkers in Water

Page 1 of 2

Applicable Countermeasures / Chemical Class	CONTAINMENT				DISPLACEMENT			TREATMENT															DISPOSAL			
	Dikes, Berms and Dams	Trenches	Curtain Barriers	Stream Diversion	Dredging - Mechanical (1)	Pumping	Dispersion/Dilution	Activated Carbon	Natural Inorganic (3) Sorbents	Synthetic Sorbents	Gravity Separation	Membrane Separation	Coagulation/Flocculation	Extraction	Chelation/Sequestration	Ion Exchange - Anionic	Ion Exchange - Cationic	Neutralize w/acid	Neutralize w/base (5)	Oxidation	Precipitation (6)	Biological Treatment (7)	Incineration	Wet Air Oxidation	Landfill	Deep Well Injection
Acidic compounds, organic	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓					✓			✓	✓		✓	✓
Acidic compounds, inorganic	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓		✓			✓				✓		✓	✓
Alcohols and glycols	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓						✓			✓		✓	✓
Aldehydes	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓						✓		✓	✓		✓	✓
Aliphatics, halogenated	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓						✓			✓		✓	✓
Amides, anilides and imides	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓
Amines, alkyl	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓
Amines, aryl	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓								✓	✓		✓	✓
Aromatics	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓								✓	✓		✓	✓
Aromatics, halogenated	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓								✓	✓		✓	✓
Azo compounds	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓
Basic compounds	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓				✓		✓			✓		✓	✓
Chromates	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓				✓		✓		✓	✓
Cyanates	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓			✓						✓		✓	✓
Cyanides and nitriles	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓			✓		✓	✓	✓	✓	✓
Epoxides	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓
Esters	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓		✓							✓		✓	✓
Ethers	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓
Halides, alkyl	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓									✓		✓	✓
Halides, inorganic	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	(4)✓	✓	✓				✓		✓		✓	✓
Heavy metals	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	✓
Hydrazines and hydrazides	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓				✓					✓		✓	✓
Ketones	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓								✓	✓		✓	✓
Nitromycin	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓
Nitrates and nitriles	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓				✓	✓		✓		✓	✓
Nitro compounds	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓

Table 2B. Soluble Sinkers in Water

Page 2 of 2

Applicable Countermeasures / Chemical Class	CONTAINMENT				DISPLACEMENT			TREATMENT															DISPOSAL			
	Dikes, Berms and Dams	Trenches	Curtain Barriers	Stream Diversion	Dredging - Mechanical (1)	Pumping	Dispersion/Dilution (2)	Activated carbon	Natural Inorganic Sorbents (3)	Synthetic Sorbents	Gravity Separation	Membrane Separation	Coagulation/Flocculation	Extraction	Chelation/Sequestration	Ion Exchange - Anionic	Ion Exchange - Cationic	Neutralize w/acid (5)	Neutralize w/base (6)	Oxidation	Precipitation (6)	Biological Treatment (7)	Incineration	Wet Air Oxidation	Landfill	Deep Well Injection
Nitroso compounds	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓
Organic Ammonium compounds	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓		✓	✓	✓					✓		✓	✓
Organometallics	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓		✓		✓		✓		✓	✓
Organophosphates	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓					✓				✓		✓	✓
Oxides	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓							✓		✓		✓	✓
Peroxides	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓
Phenols and cresols	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓			✓	✓		✓	✓		✓	✓
Phosphates and phosphonates	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓				✓	✓				✓		✓	✓
Phosphorous and compounds	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓			✓		✓				✓		✓	✓
Streptozotocin	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓									✓		✓	✓
Sulfates	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓			✓		✓		✓		✓		✓	✓
Sulfides and mercaptons	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓				✓			✓		✓	✓
Sulfites	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓			✓			✓		✓	✓
Sulfones, sulfoxides & sulfonates	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓							✓		✓	✓
Ureas	✓	✓	✓	✓	✓	✓	✓				✓	✓		✓									✓		✓	✓

(1) Applicable to immobilized masses of particulate only

(2) Reduce contaminant levels below toxic level through flow augmentation, mechanical mixing, or chemical dispersants. Applicable to small spills in remote areas only!

(3) Metal oxides and glauconitic greensands

(4) Excluding ammonium halides

(5) Treatment with sodium barcarbonate or lime recommended

(6) Treat with stoichiometric amounts of sulfide except chromates, treat chromates with bisulfite

(7) Potentially biodegradable

Table 3B. Insoluble Floaters on Water

Page 1 of 1

Applicable Countermeasures / Chemical Class	CONTAINMENT									TREATMENT																DISPOSAL				
	Dikes, Berms and Dams	Surface Booms	Curtain Barriers	Foam Covers (1)	Synthetic Membrane Cover	Stream Diversion	Skimming	Pumping	Dispersion/Dilution (2)	Activated carbon	Natural Organic Sorbents	Synthetic Sorbents	Granular Media Filtration	Gravity Separation	Evaporation	Aeration	Steam Stripping	Knockdown Spray (1)	Extraction	Gels	Ion Exchange	Hydrolysis	Neutralization	Oxidation	Biological Treatment (3)	Incineration	Open Burning (4)	Wet Air Oxidation	Landfill	Deep Well Injection
Aliphatics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓		✓		✓		✓		✓	✓	✓	✓		✓	✓
Aliphatics, halogenated	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓		✓		✓		✓		✓			✓	✓
Aromatics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓		✓				✓	✓	✓	✓		✓	✓
Esters	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓		✓		✓			✓	✓	✓		✓	✓
Ethers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓				✓		✓	✓	✓	✓		✓	✓
Halides, alkyl	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓						✓			✓	✓
Nitroso compounds	✓	✓	✓		✓	✓	✓	✓	✓					✓		✓					✓			✓		✓			✓	✓
Olefins	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓		✓		✓					✓	✓	✓		✓	✓
Phenols and cresols	✓	✓	✓		✓	✓	✓	✓	✓	✓				✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Sulfones, sulfoxides, & sulfonates	✓	✓	✓		✓	✓	✓	✓	✓					✓		✓		✓	✓							✓			✓	✓

(1) Reduce vapor hazards

(2) Reduce contaminant levels below toxic level through flow augmentation, mechanical mixing, or chemical dispersants. Applicable to small spill in remote areas only!

(3) Potentially biodegradable

(4) Applicable to small spills in remote areas only! Air monitoring may be necessary

Table 4B. Soluble Floaters on Water

Page 1 of 1

Applicable Countermeasures / Chemical Class	CONTAINMENT				DISPLACEMENT			TREATMENT															DISPOSAL			
	Dikes, Berms and Dams	Surface Booms (1)	Curtain Barriers (1)	Stream Diversion	Skimming (1)	Pumping (1)	Dispersion/Dilution (2)	Membrane Separation	Aeration	Steam Stripping (3)	Knockdown Spray (4)	Activated Carbon	Extraction (5)	Precipitation	Gels (6)	Ion Exchange - Anionic	Ion Exchange - Cationic	Neutralize w/acid (7)	Neutralize w/base	Hydrolysis	Oxidation	Biological Treatment (8)	Incineration	Wet Air Oxidation	Landfill	Deep Well Injection
Acidic compounds, organic	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓	✓			✓			✓	✓		✓	✓
Alcohols and glycols	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓									✓	✓	✓		✓	✓
Aldehydes	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓				✓		✓	✓	✓		✓	✓
Alkali metals	✓	✓	✓	✓	✓	✓	✓	✓		✓								✓					✓		✓	✓
Amines, alkyl	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓			✓			✓	✓	✓		✓	✓
Amines, aryl	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓			✓			✓	✓	✓		✓	✓
Aromatics	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓									✓		✓		✓	✓
Basic Compounds	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓						✓	✓					✓		✓	✓
Cyanides and nitriles	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓	✓	✓	✓	✓	✓	✓
Ethers	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓						✓		✓	✓	✓	✓		✓	✓
Esters	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓					✓		✓	✓		✓	✓
Hydrazines and hydrazides	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓												✓		✓	✓
Ketones	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓							✓	✓		✓	✓
Nitro compounds	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓											✓	✓		✓	✓
Nitroso compounds	✓	✓	✓	✓	✓	✓	✓	✓		✓												✓	✓		✓	✓
Olefins	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓								✓		✓	✓
Oxides, alkyline	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓											✓		✓	✓

(1) Rapid deployment necessary

(2) Reduce contaminant levels below toxic level through flow augmentation, mechanical mixing or chemical dispersants. Applicable to small spills in remote areas only!

(3) Applicable to liquids only

(4) Reduce vapor hazard

(5) Extract with vegetable oil

(6) Multipurpose gelling agent (MGA)

(7) Treat with dilute and/or removable acids

(8) Potentially biodegradable

Table 5B. Liquids on Land

Page 1 of 2

Applicable Countermeasures / Chemical Class	CONTAINMENT						DISPLACEMENT			TREATMENT														DISPOSAL						
	Dikes, Berms and Dams	Trenches	Barriers in Soil	Chemically Active Covers	Synthetic Membrane Liners (1)	Foam Covers (2)	Excavation	Pumping	Dispersion/Dilution (3)	Natural Organic Sorbents	Natural Inorganic Sorbents	Synthetic Sorbents	Cryogenic Cooling with CO_2 and LN_2 (2)	Evaporation (4)	Knockdown Spray (2)	Extraction (5)	Cements	Gels	Lime	Hydrolysis	Neutralize	Oxidation	Biological Treatment (6)	Incineration	Open Burning (4)	Wet Air Oxidation	Vitrification	Pyrolysis	Landfill	Deep Well Injection
Acidic compounds, organic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓				✓	✓
Acidic compounds, inorganic	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓		✓								✓	✓
Alcohols and glycols	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓				✓	✓	✓	✓				✓	✓
Aldehydes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓			✓	✓
Aliphatics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓		✓						✓	✓			✓	✓	✓
Aliphatics, halogenated	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓					✓	✓
Amides, anilides and imides	✓	✓	✓	✓	✓		✓	✓	✓							✓				✓				✓	✓				✓	✓
Amines, alkyl	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓				✓	✓
Amines, aryl	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓				✓	✓
Aromatics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓			✓	✓	✓
Aromatics, halogenated	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓					✓	✓
Basic compounds	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓			✓													✓	✓
Cyanates	✓	✓	✓	✓	✓		✓	✓	✓							✓								✓					✓	✓
Cyanides and nitriles	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓		✓			✓	
Epoxides	✓	✓	✓	✓	✓		✓	✓	✓							✓								✓	✓				✓	✓
Esters	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓				✓	✓
Ethers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓		✓				✓	✓				✓	✓
Halides, alkyl	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓		✓		✓					✓	✓
Halides, inorganic	✓	✓	✓	✓	✓		✓	✓	✓						✓	✓													✓	✓
Heavy metals	✓	✓	✓	✓	✓		✓	✓	✓		✓				✓	✓	✓	✓	✓								✓		✓	✓
Hydrazines and hydrazides	✓	✓	✓	✓	✓		✓	✓	✓						✓	✓								✓	✓	✓			✓	✓
Ketones	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓				✓	✓
Nitro compounds	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓				✓	✓						✓		✓		✓			✓	✓
Nitroso compounds	✓	✓	✓	✓	✓		✓	✓	✓							✓								✓					✓	✓
Olefins	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓			✓	✓
Organophosphates	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓				✓	✓	✓			✓		✓		✓				✓	✓	✓

Table 5B. Liquids on Land (Continued)

Page 2 of 2

Applicable Countermeasures / Chemical Class	CONTAINMENT						DISPLACEMENT			TREATMENT														DISPOSAL						
	Dikes, Berms and Dams	Trenches	Barriers in Soil	Chemically Active Covers	Synthetic Membrane (1) Liners	Foam Covers (2)	Excavation	Pumping	Dispersion/Dilution (3)	Natural Organic Sorbents	Natural Inorganic Sorbents	Synthetic Sorbents	Cryogenic Cooling with CO_2 and LN_2 (2)	Evaporation (4)	Knockdown Spray (2)	Extraction (5)	Cements	Gels	Lime	Hydrolysis	Neutralize	Oxidation	Biological Treatment (6)	Incineration	Open Burning (4)	Wet Air Oxidation	Vitrification	Pyrolysis	Landfill	Deep Well Injection
Oxides	✓	✓	✓	✓	✓		✓	✓	✓		✓		✓		✓	✓		✓					✓	✓					✓	✓
Peroxides	✓	✓	✓	✓	✓		✓	✓	✓							✓								✓					✓	✓
Phenols and cresols	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓				✓	✓
Phosphorous and compounds	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓			✓								✓				✓	✓	✓
Sulfates	✓	✓	✓	✓	✓		✓	✓	✓					✓		✓								✓				✓	✓	✓
Sulfides and mercaptans	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓	✓	✓				✓		✓		✓		✓	✓	✓
Sulfites	✓	✓	✓	✓	✓		✓	✓	✓					✓		✓													✓	✓

(1) Synthetic membrane used to line trenches or portable catch basins used to contain spilled material

(2) Reduce vapor hazards

(3) Flush spill area with water after free material has been removed

(4) Applicable to small spills in remote areas only. Air monitoring may be necessary

(5) Water soluble and water miscible organics in soil

(6) Potentially biodegradable

Table 6B. Particulate Solids on Land

Page 1 of 2

Applicable Countermeasures / Chemical Class	CONTAINMENT			DISPLACEMENT			TREATMENT							DISPOSAL				
	Synthetic Membrane Covers	Foam Covers	Water Covers (1)	Excavation	Vacuuming	Dispersion/Dilution (2)	Knockdown Spray (3)	Extraction (4)	Solidification/ Stabilization (5)	Hydrolysis - Acid	Hydrolysis - Alkaline	Oxidation	Biological Treatment (7)	Incineration	Wet Air Oxidation	Vitrification	Pyrolysis	Landfill
Acidic compounds, inorganic	✓	✓		✓	✓	✓		✓	✓									✓
Acidic compounds, organic	✓	✓		✓	✓	✓		✓	✓			✓ (6)	✓	✓	✓		✓	✓
Aldehydes	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓
Aliphatics, halogenated	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓
Alkali metals	✓	✓		✓	✓	✓			✓					✓	✓		✓	✓
Amides, anilides, and imides	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓
Amines, alkyl	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓
Amines, aryl	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓
Aromatics	✓	✓		✓	✓	✓	✓	✓	✓			✓		✓	✓		✓	✓
Aromatics, halogenated	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓
Asbestos	✓	✓		✓	✓	✓	✓		✓									✓
Azo compounds	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Basic compounds	✓	✓		✓	✓	✓		✓	✓					✓	✓		✓	✓
Chromates	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Cyanates	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Cyanides and nitriles	✓	✓		✓	✓	✓		✓	✓		✓	✓		✓	✓		✓	✓
Epoxides	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Esters	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓
Halides, inorganic	✓	✓		✓	✓	✓			✓					✓				✓
Heavy metals	✓	✓		✓	✓	✓	✓		✓					✓		✓		✓
Hydrazines and hydrazides	✓	✓		✓	✓	✓		✓	✓		✓			✓	✓		✓	✓
Ketones	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Mitromycin	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Nitrates and nitrites	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Nitro compounds	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Nitroso compounds	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Olefins	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓

Table 6B. Particulate Solids on Land (Continued)

Page 2 of 2

Applicable Countermeasures / Chemical Class	CONTAINMENT			DISPLACEMENT			TREATMENT							DISPOSAL				
	Synthetic Membrane Covers	Foam Covers	Water Covers (1)	Excavation	Vacuuming	Dispersion/Dilution (2)	Knockdown Spray (3)	Extraction (4)	Solidification/ Stabilization (5)	Hydrolysis - Acids	Hydrolysis - Alkaline	Oxidation	Biological Treatment (7)	Incineration	Wet Air Oxidation	Vitrification	Pyrolysis	Landfill
Organic Ammonium compounds	✓	✓		✓	✓	✓	✓	✓	✓			✓		✓	✓		✓	✓
Organometallics	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Organophosphates	✓	✓		✓	✓	✓	✓	✓	✓		✓			✓	✓		✓	✓
Oxides	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Phenols and cresols	✓	✓		✓	✓	✓	✓	✓	✓			✓		✓	✓		✓	✓
Phosphates and phosphonates	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Phosphorous and compounds	✓	✓	✓	✓	✓	✓		✓	✓					✓	✓		✓	✓
Streptozotocin	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Strychnine and salts	✓	✓		✓	✓	✓	✓		✓					✓	✓		✓	✓
Sulfates	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Sulfides and mercaptans	✓	✓		✓	✓	✓	✓	✓	✓			✓		✓	✓		✓	✓
Sulfites	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓
Sulfones, sulfoxides & sulfonates	✓	✓		✓	✓	✓	✓	✓	✓	✓				✓	✓		✓	✓
Ureas	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓		✓	✓

(1) For phosphorous spills, flush diked area with water to cover spill. Do not put water on phosphorous pentasulfide, aluminum phosphide, or zinc phosphide

(2) For small spills, shovel spilled material into dry container and cover, move container and flush area with water

(3) Use knockdown spray to reduce vapor or entrainment of dust. Do not use on water reactive compounds

(4) Water soluble and water miscible organics in soil

(5) Use of asphalt inapplicable to iron salts, aluminum salts, strong oxidizers and if significant concentrations of lead, mercury, or arsenic are present

(6) Pyrethrine oxidized by air

(7) Potentially biodegradable compounds

Table 7B. Compressed Gases into Air

Page 1 of 1

Applicable Countermeasures / Chemical Class	CONTAINMENT				DISPLACEMENT	TREATMENT				DISPOSAL
	Dikes, Berms and Dams	Trenches (1)	Patching, Plugging of Container	Foam Covers (2)	Dispersion/Dilution (4)	Cryogenic cooling with CO_2 and IN_2 (2)	Cryogenic cooling with water (5)	Knockdown Spray (2)	Sorption (6)	Open Burning (4)
Ammonia	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Aldehydes	✓	✓	✓		✓		✓	✓	✓	✓
Amines, alkyl	✓	✓	✓		✓		✓	✓	✓	✓
Cyanides and nitriles	✓	✓	✓		✓		✓	✓	✓	
Halides, alkyl	✓	✓	✓	✓(3)	✓	✓	✓	✓	✓	
Halogens	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Oxides	✓	✓	✓	✓(3)	✓		✓	✓	✓	
Sulfides and mercaptans	✓	✓	✓		✓(4)	✓	✓	✓	✓	

(1) Construct dike or trench around container to hold run-off if using knockdown spray

(2) Vapor hazard reduction. Do not get water on leak area

(3) Protein or fluoroprotein foams recommended

(4) Small amount in remote areas. Air monitoring will be necessary

(5) In case of fire, cool containers exposed to flames; do not put water on leak area

(6) For vapors heavier than air use commercial protective covers/sorbents to place over sewer openings, manholes, vents, and grates in vicinity of spill to prevent vapor entrance

Table 1C. Insoluble Sinkers

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Curtain Barriers	C	In-situ	NA	Neat Diss	<1 day	X	X		X	X			X					TEC		$200-300/ft	1.1.3.2	Max. current - 1-2 knots Max. depth - 2-5 feet Max. waves - 6 feet
Dams, Berms, Dikes	C	In-situ	NA	Neat Diss	varies		X	X	X	X	X							HEO CE		$4/ cu yd	1.1.1	Earth moving equipment may require special access
Stream Diversion	C	In-situ	NA	Neat Diss	varies		X		X		X		X	X				HEO CE			1.1.5	Earth moving equipment may require special access Power required for pumps. Mobile unit available.
Synthetic Membrane Cover	C	In-situ	NA	Neat Diss	varies	X			X	X	X		X					TEC PRO		3-4¢/ sq.ft. (1972)	1.2.3	Material must be chemically compatible with hazardous substance Navigable water only
Trenches	C	In-situ	NA	Neat Diss	varies		X	X	X	X	X		X					HEO CE			1.1.2	Underwater trenches may require special equipment
Dispersion	D	In-situ	Gross	Neat Diss	>1 day							X							X		1.3.5	Bad weather and rough water may enhance dispersion. Type of HS dictates whether dispersion usable in populated areas.
Dredging	D	In-situ	Gross	Neat	>1 day				X	X	X					X		TEC CE	X	$5-15/ yd^3	1.3.1	Perimeter of spill must be known. Requires large boat/barge.
Pumping	D	In-situ	NA	Neat Diss	varies								X	X		X		TEC		$50-60/ hr	1.3.4	~32' height limit for vacuum pumping. May need corrosion/explosion proof pumps.
Activated Carbon Column	T.	On-site	Moderate Polish	Diss	>1 day						X		X	X	X	X		TEC PRO		2-23¢/ gal 50-55¢/ lb	2.1.1	Spent carbon must be regenerated or disposed of.

Table 1C. Insoluble Sinkers (Continued)

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	LIMITATIONS							REQUIREMENTS							Unit Cost	Text Section	Comments
						Environmental																
						Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits			
Biological Treatment	T	Off-Site	Moderate Polish	Neat Diss	Varies								X					STE	X		4.0	May require special bacteria.
Biological Treatment	T	In-situ	Moderate Polish	Diss.	>1 day			X	X	X								STE			4.0	May require special bacteria.
Coagulation/ Flocculation	T	On-Site	Moderate	Diss.	< ½ day								X	X		X		CHE CH TEC			3.1	1 stage of treatment process. Usually followed by filtration or gravity separation.
Granular Media Filtration	T	On-Site	Gross	Neat	>1 day								X	X		X		STE TEC			2.3	1 stage of treatment process. Follows flocculation/coagulation & precedes polishing.
Gravity Separation	T	On-Site	Gross	Neat	<1 day								X			X		TEC			2.4	1 stage of treatment process Follows flocculation/coagulation & precedes polishing, May require special equipment.
Incineration		On-Site	Moderate Polish (Disposal)	Neat Diss.	<1 day	X					X	X	X		X	X	X	PRO	X		5.2	May require stack monitoring. May produce toxic gases/ashes.
Incineration		Off-site	Moderate Polish (Disposal)	Neat Diss	<1 day								X		X	X	X	PRO	X	$395-791/ ton solid $53-237/ ton liq.	5.2	May require stack monitoring. May produce toxic gases/ashes
Ion Exchange (Anionic/Cationic)	T	On-site	Moderate Polish	Diss	>1 day						X		X	X	X	X		CHE TEC			3.4	Proper selection of resin is very important
Neutralization	T	On-site	Moderate Polish	Diss Neat	>1 day						X		X	X	X		X	TEC CHE			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.

Table 1C. Insoluble Sinkers (Continued)

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	LIMITATIONS: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	REQUIREMENTS: Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Neutralization	T	In-situ	Moderate Polish	Neat Diss	<1 day	X	X		X	X					X		X	CH TEC			3,6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.
Oxidation	T	On-site	Moderate Polish	Diss	>1 day						X		X	X	X		X	CH CHE TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction.
Oxidation	T	In-situ	Moderate Polish	Diss	<1 day	X	X		X	X					X		X	CH TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction. Main cost is chemicals.
Precipitation	T	On-site	Gross Polish	Diss	>1 day						X		X	X	X	X	X	CH CHE TEC			3.9	Precipitating chemicals may be hazardous.
Precipitation	T	In-situ	Gross Polish	Diss	<1 day	X	X		X	X					X	X	X	CH TEC			3.9	Precipitation chemicals may be hazardous. Toxic precipitates should be removed and disposed of.
Synthetic Sorbents	T	In-situ	Gross	Neat	<1 day	X			X	X						X		TEC			2.1.4	
Synthetic Sorbent Column	T	On-site	Moderate Polish	Diss	>1 day						X		X	X	X	X		CH TEC			2.1.4	
Wet Air Oxidation	T	Off-site	Moderate Polish (disposal)	Diss	<1 day								X					TEC	X		5.3	Typically used for industrial waste water treatment.
Landfill		Off-site	(Disposal)	Neat Diss	Varies													TEC	X	$55-240/ton	5.5	Requires containerization or dewatering. May require pretreatment and/or solidification.

Table 1C. Insoluble Sinkers (Continued)

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Deep Well Injection		Off-site	(Disposal)	Neat Diss	Varies													TEC	X	$.06-$1/gal	5.6	Service generally contracted. Extensive geologic study to determine adequate well location.

Legend:

STE = Sanitary Engineer
CHE = Chemical Engineer
CH = Chemist
HEO = Heavy Equipment Operator
PRO = Professional
TEC = Technician
NA = Not Applicable
CE = Civil Engineer

Table 2C. Soluble Sinkers

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Curtain Barriers	C	In-situ	NA	Neat Diss	<1 day	X	X		X	X			X					TEC		$200-300/ ft.	1.1.3.2	Max current - 1-2 knots Max depth - 25 ft. Max waves - 6 ft.
Dams, Berms, Dikes	C	In-situ	NA	Neat Diss	Varies		X	X	X	X	X							HEO CE		$4/yd^3	1.1.1	Earth moving equipment may require special access.
Stream Diversion	C	In-situ	NA	Neat Diss	Varies		X		X		X		X	X				HEO CE			1.1.5	Earth moving equipment may require special access. Power required for pumps. Mobile unit available.
Dispersion/Dilution	D	In-situ	Gross	Neat Diss.	Varies							X							X		1.3.5	Bad weather & rough water may enhance dispersion. Type of HS dictates whether technique is usable in populated areas.
Dredging	D	In-situ	Gross	Neat	>1 day				X	X	X					X		TEC CE	X	$5-15/ yd^3	1.3.1	Perimeter of spill must be known. Requires large boat/barge. Must be rapidly deployed.
Pumping	D	In-situ	Gross	Neat Diss.	Varies			X	X	X	X		X	X		X		TEC		$50-60/hr	1.3.4	~32' height limit for vacuum pumping. May need corrosion/explosion proof pumps.
Trenches	C	In-situ	NA	Neat Diss.	Varies		X	X	X	X	X		X					HEO CE			1.1.2	Underwater trenches may require special equipment.
Activated Carbon Column	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X	X		TEC CHE		.0004-.23/ gal $050 - $5/lb	2.1.1	Spent carbon must be regenerated or disposed of.

Table 2C. Soluble Sinkers (Continued)

Countermeasure	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	LIMITATIONS Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	REQUIREMENTS: Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Biological Treatment	T	Off-site	Moderate Polish	Diss.	>1 day								X					STE	X		4.0	May require special bacteria cultures.
Biological Treatment	T	In-situ	Moderate Polish	Diss.	>1 day			X	X	X								STE			4.0	May require special bacteria cultures.
Chelation/ Sequestration	T	On-site	Moderate	Diss.	<1 day								X	X	X	X		CHE CH TEC			3.3.1	Must be followed by an extraction e.g. with vegetable oil.
Coagulation/ Flocculation	T	On-site	Moderate	Diss.	<½ day								X	X		X		CHE CH TEC			3.1	1 stage of treatment process. Usually followed by filtration or gravity separation.
Extraction	T	On-site	Moderate	Diss.	>1 day						X		X	X	X	X		CH CHE TEC			3.2	Proper choice of solvent very important.
Gravity Separation	T	On-site	Gross	Neat	<1 day								X			X		TEC			2.4	1 stage of treatment process, Follows precipitation or flocculation/ coagulation and precedes polishing.
Incineration		On-site	Moderate Polish (Disposal)	Neat Diss.	<1 day	X					X	X	X		X	X	X	PRO	X		5.2	May require stack monitoring. May produce toxic gas/ash.
Incineration		Off-site	Moderate Polish (Disposal)	Neat Diss.	<1 day								X		X	X	X	PRO	X	$395 - 791/ ton solid $53-237/ ton liq.	5.2	May require stack monitoring. May produce toxic gas/ash.

Table 2C. Soluble Sinkers (Continued)

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	LIMITATIONS: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	REQUIREMENTS: Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Ion Exchange (Anionic & Cationic)	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X	X		CHE TEC			3.4	Proper selection of resin is very important.
Membrane Separation	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X	X		PRO TEC			2.7	
Natural Inorganic Sorbents	T	In-situ	Gross	Neat	<1 day	X			X	X						X		TEC			2.1.3	Sorbent must sink. Must be hydrophilic.
Natural Inorganic Sorbents Column	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X	X		CHE TEC			2.1.3	Sorbent must be hydrophilic.
Neutralization	T	On-site	Moderate Polish	Neat Diss.	>1 day						X		X	X	X		X	CH TEC CHE			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.
Oxidation	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X		X	CH CHE			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction.
Oxidation	T	In-site	Moderate Polish	Diss.	>1 day											X	X	CH TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction. Main cost is chemicals.
Precipitation	T	On-site	Gross Polish	Diss.	>1 day						X		X	X	X	X	X	CH CHE TEC			3.9	Precipitated chemicals may be hazardous.
Precipitation	T	In-situ	Gross Polish	Diss.	<1 day	X	X		X	X					X	X	X	CH TEC			3.9	Precipitated chemicals may be hazardous. Toxic precipitates should be removed & disposed of.

Table 2C. Soluble Sinkers (Continued)

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	LIMITATIONS: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	REQUIREMENTS: Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Synthetic Sorbents	T	In-situ	Gross	Neat	<1 day	X			X	X						X		TEC			2.1.4	Sorbent must sink. Must be hydrophilic.
Synthetic Sorbent Column	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X	X		CHE TEC			2.1.4	Sorbent must be hydrophilic.
Wet Air Oxidation		Off-site	Moderate Polish (Disposal)	Diss.	<1 day								X					TEC			5.3	Typically used for industrial waste water treatment.
Landfill		Off-site	(Disposal)	Neat Diss.	Varies											X		TEC	X	$55-240/ton	5.5	Requires containerization or dewatering. May require pretreatment and/or solidification.
Deep Well Injection		Off-site	(Disposal)	Neat Diss.	>1 day							X	X	X	X	X			X	$.06-1.00/gal.	5.6	Service generally contracted. Extensive geologic study to determine adequate well location.

Legend:

STE = Sanitary Engineer
CHE = Chemical Engineer
CH = Chemist
HEO = Heavy Equipment Operator
PRO = Professional
TEC = Technician
NA = Not Applicable
CE = Civil Engineer

Table 3C. Insoluble Floaters

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	LIMITATIONS							REQUIREMENTS							Unit Cost	Text Section	Comments
						Environmental																
						Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits			
Curtain Barriers	C	In-situ	NA	Neat Diss.	<1 day	X	X		X	X			X					TEC		$200-300/ft	1.1.3.2	Max current - 1-2 knots Max depth - 25 ft. Max waves - 6 ft.
Dams, Berms, Dikes	C	In-situ	NA	Neat Diss.	Varies		X	X	X	X	X		X					HEO CE		$4/yd^3	1.1.1	Earth moving equipment may require special access.
Foam Covers	C	In-situ	NA	Neat Diss.	<½ day	X	X	X					X	X		X		FR TEC		$5/ gal spill	1.2.4	Very important to use foam which is chemically compatible with hazardous material.
Stream Diversion	C	In-situ	NA	Neat Diss.	Varies		X		X		X		X	X				HEO CE			1.1.5	Earth moving equipment may require special access. Power required for pumps. Mobile unit available.
Synthetic Membrane Covers	C	In-situ	NA	Neat Diss.	<1 day	X	X	X	X	X	X					X		PRO TEC			1.2.3	Membrane must be chemically compatible with hazardous material. Feasible on small spills on small water bodies.
Dispersion	D	In-situ	Gross	Neat Diss.	>1 day					X		X						TEC	X		1.3.5	Bad weather and rough water may enhance dispersion. Type of HS dictates whether dispersion usable in populated areas.
Pumping	D	In-situ	Gross	Neat Diss.	Varies			X	X	X	X		X	X		X		TEC		$50-60/ hr	1.3.4	~32' height limit for vacuum pumping. May need corrosion/explosion proof pumps.
Skimming	D	In-situ	Gross	Neat	Varies				X	X			X	X		X		TEC			1.3.3	~32' height limit for vacuum pumping. May need corrosion/explosion proof pumps.
Surface Booms	C	In-situ	NA	Neat	<1 day	X	X		X	X			X					TEC		$6/ ft	1.1.3.1	Current - <2 knots Waves - 2-4 ft. Difficult in high winds. Rapid deployment.

Table 3C. Insoluble Floaters (Continued)

						LIMITATIONS							REQUIREMENTS									
						Environmental																
	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Sorbents	T	In-situ	Gross	Neat	<1 day	X	X	X	X	X			X			X	X	TEC			2.1	May be hard to apply in bad weather. Special equipment can facilitate sorbent broadcasting and recovery. Dust mask may be required.
Activated Carbon Column	T	On-site	Moderate Polish.	Diss.	>1 day						X		X	X	X	X		TEC CHE		$.0004-.23/gal $0.50-$5/lb	2.1.1	Spent carbon must be regenerated or disposed of.
Aeration	T	In-situ	Moderate -Polish	Diss.	>1 day	X		X						X	X		X	PRO TEC	X		2.8.1	May pollute the atmosphere. Can enhance other treatment methods, e.g. biodegradation, oxidation.
Aeration	T	On-site	Moderate -Polish	Diss.	>1 day			X			X		X	X	X		X	CHE PRO TEC	X		2.8.1	May pollute the atmosphere. Can enhance other treatment methods, e.g. biodegradation, oxidation.
Biological Treatment	T	Off-site	Moderate -Polish	Diss.	>1 day													STE	X		4.0	May require special bacteria.
Biological Treatment	T	In-situ	Moderate -Polish	Diss.	>1 day			X	X	X								STE			4.0	May require special bacteria.
Evaporation	T	In-situ	Gross-Moderate	Diss. Neat	Varies	X	X	X				X			X		X				2.5	Wind direction may preclude this countermeasure. Potential fire/toxic vapor hazard.
Extraction	T	On-site	Moderate	Diss.	>1 day						X		X	X	X	X		CH CHE TEC			3.2	Proper choice of solvent very important.
Gels	T	In-situ	NA	Neat Diss.	<½ day	X	X	X	X	X						X	X	CH TEC		$.50-2.50/lb	3.3.3	Avoid skin contact and inhalation. Low temperatures retard gelling time.

Table 3C. Insoluble Floaters (Continued)

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasure	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Granular Media Filtration	T	On-site	Gross	Neat	>1 day								X	X		X		STF TEC			2.3	1 stage if treatment process follows flocculation/ coagulation and precedes polishing.
Gravity Separation	T	On-site	Gross	Neat	>1 day								X			X		TEC			2.4	May require special equipment.
Hydrolysis	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X			CH CHE TEC			3.5	Reaction products may be hazardous. May require pre- and post- pH adjustment.
Incineration		On-site	Moderate-Polish (disposal)	Neat Diss.	<1 day	X					X	X	X		X	X	X	PRO	X		5.2	May require stack monitoring. May produce toxic gas/ashes.
Incineration		Off-site	Moderate-Polish (disposal)	Neat Diss.	<1 day								X		X	X	X	PRO	X	$395-791/ ton solid $53-237/ ton liq.	5.2	May require stack monitoring. May produce toxic gas/ashes.
Ion Exchange	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X	X		CHE TEC			3.4	Proper selection of resin is very important.
Knockdown Spray	T	In-situ	NA	Vapor	<½ day	X	X	X						X				FR			2.9	Need to contain the hazardous runoff water.
Membrane Separation	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X	X		PRO TEC			2.7	
Neutralization	T	On-site	Moderate-Polish	Neat Diss.	>1 day						X		X	X	X		X	CH CHE TEC			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.

Table 3C. Insoluble Floaters (Continued)

Page 4 of 5

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Neutralization	T	In-situ	Moderate-Polish	Neat Diss.	<1 day	X	X		X	X					X		X	CH TEC			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.
Open Burning		In-situ	Moderate	Neat	<1 day	X	X		X	X		X				X	X	FR	X		5.1	May require disposal of toxic ash. May produce toxic smoke.
Oxidation	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X		X	CH CHE TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction.
Oxidation	T	In-situ	Moderate-Polish	Diss.	<1 day	X	X		X	X					X		X	CH TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction. Main cost is chemicals.
Steam Stripping	T	On-site	Polish	Diss.	>1 day						X		X	X		X		CHE TEC			2.8.2	Requires steam source.
Synthetic Sorbents	T	In-situ	Gross	Neat	<1 day	X			X	X						X		TEC			2.1.4	
Synthetic Sorbent Column	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X	X		CHE TEC			2.1.4	
Wet Air Oxidation		Off-site	Moderate-Polish (Disposal)	Diss.	<1 day								X					TEC	X		5.3	Typically used for industrial waste water treatment.
Landfill		Off-site	(Disposal)	Neat Diss.	Varies											X		TEC	X	$55-240/ ton	5.5	Requires containerization or dewatering. May require pretreatment and/or solidification.
Deep Well Injection		Off-site	(Disposal)	Neat Diss.	Varies											X		TEC	X	$.06-1.00/ gal	5.6	Service generally contracted. Extensive geologic study to determine adequate well location.

Table 3C. Insoluble Floaters (Continued)

Legend:

STE = Sanitary Egnineer
CHE = Chemical Engineer
CH = Chemist
HEO = Heavy Equipment Operator
PRO = Professional
TEC = Technician
NA = Not Applicable
CE = Civil Engineer
FR = Firefighter

Table 4C. Soluble Floaters

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Curtain Barriers	C	In-situ	NA	Neat Diss.	Varies	X	X		X	X			X					TEC			1.1.3.2	Max current - 1-2 knots Max depth - 25 feet Max Waves - 6 feet
Dams, Berms, Dikes	C	In-situ	NA	Neat Diss.	Varies		X	X	X	X	X							HEO CE		$4/yd^3	1.1.1	Earth moving equipment may require special access.
Foam Covers	C	In-situ	NA	Neat Diss.	<½ day	X	X	X					X	X		X		FR TEC		$5/ gal	1.2.5	Very important to use a foam which is chemically compatible with the hazordous material.
Stream Diversion	C	In-situ	NA	Neat Diss.	Varies		X		X		X		X	X				HEO CE			1.1.5	Earth moving equipment may require special access. Power required for pumps. Mobile unit available.
Surface Booms	C	In-situ	NA	Neat	>1 day	X	X		X	X			X					TEC		$6/ft	1.1.3.1	Current - < 2 knots Waves - 2-4 feet Difficult in high winds. Requires rapid deployment.
Dispersion/Dilution	D	In-situ	Gross	Neat Diss.	>1 day							X						TEC	X		1.3.5	Bad weather and rough weather may enhance dispersion. Type of HS dictates whether dispersion usable in populated areas.

Table 4C. Soluble Floaters (Continued)

Page 2 of 5

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Pumping	D	In-situ	Gross	Neat Diss	Varies			X	X	X	X		X	X		X		TEC		$50-60/hr	1.3.4	~32' height limit for vacuum pumping. May need corrosion/explosion proof pumps.
Skimming	D	In-situ	Gross	Neat	Varies				X	X			X	X		X		TEC			1.3.3	~32' height limit for vacuum pumping. May need corrosion/explosion proof pumps.
Activated Carbon Column	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X	X		TEC CHE		$.0004-.23/gal $0.50-$5/lb	2.1.1	Spent carbon must be regenerated or disposed of.
Aeration	T	In-situ	Moderate Polish	Diss.	>1 day	X			X					X	X		X	PRO TEC	X		2.8.1	May pollute the atmosphere. Can enhance other treatment methods e.g., biodegration, oxidation.
Aeration	T	On-site	Moderate Polish	Diss.	>1 day			X			X		X	X	X		X	CHE PRO TEC	X		2.8.1	May pollute the atmosphere. Can enhance other treatment methods e.g., biodegration, oxidation.
Biological Treatment		Off-site	Moderate Polish	Diss.	>1 day								X					STE	X		4.0	May require special bacteria.
Biological Treatment		In-situ	Moderate Polish	Diss.	> 1 day			X	X	X								STE			4.0	May require special bacteria.
Extraction	T	On-site	Moderate	Diss	>1 day						X		X	X	X	X		CH CHE TEC			3.2	Proper choice of solvent very important.

Table 4C. Soluble Floaters (Continued)

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Gels	T	In-situ	NA	Neat Diss.	>½ day	X	X	X	X	X						X	X	CH TEC		$.50-2.50/ unit	3.3.3	Avoid skin contact and inhalation. Low temperatures retard gelling time.
Hydrolysis	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X			CH CHE TEC			3.5	Reaction products may be hazardous. May require pre- and post- pH adjustment.
Ion Exchange (Anionic & Cationic)	T	On-site	Moderate Polish	Diss.	>1 day						X		X	X	X	X		CHE TEC			3.4	Proper selection of resin is very important.
Incineration		On-site	Moderate Polish (Disposal)	Neat Diss.	<1 day	X					X	X	X		X	X	X	PRO	X		5.2	May require stack monitoring. May produce toxic gas/ashes.
Incineration		Off-site	Moderate Polish (Disposal)	Neat Diss.	<1 day								X		X	X	X	PRO	X	$395-791/ ton solid $53-237/ ton liq.	5.2	May require stack monitoring. May produce toxic gas/ashes.
Knockdown Spray	T	In-situ	NA	Vapor	<½ day	X	X	X						X				FR			2.9	Need to contain the hazardous run off water.
Membrane Separation	T	On-site	Moderate Polish (Disposal)	Diss.	>1 day						X		X	X	X	X		PRO TEC			2.7	
Neutralization	T	On-site	Moderate Polish (Disposal)	Neat Diss.	>1 day						X		X	X	X		X	CHE CH TEC			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.
Neutralization	T	In-situ	Moderate Polish (Disposal)	Neat Diss.	<1 day	X	X		X	X					X		X	TEC CH			3.6	Neutralizer itself may be Hazardous. May cause violent exothermic reaction.

Table 4C. Soluble Floaters (Continued)

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Oxidation	T	On-site	Moderate Polish (Disposal)	Diss	>1 day						X		X	X	X		X	CH CHE TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction.
Oxidation	T	In-situ	Moderate Polish (Disposal)	Diss	<1 day	X	X		X	X						X	X	CH TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction. Main cost is chemicals.
Precipitation	T	On-site	Gross Polish	Diss	>1 day						X		X	X	X	X	X	CH CHE TEC			3.9	Precipitated chemicals may be hazardous.
Precipitation	T	In-situ	Gross Polish	Diss	<1 day	X	X		X	X					X	X	X	CH TEC			3.9	Precipitated chemicals may be hazardous. Toxic precipitates should be removed & disposed of.
Steam Stripping	T	On-site	Polish	Diss	>1 day						X		X	X		X		CHE TEC		$1.80/ 1000 lbs	2.8.2	Requires steam sources.
Wet Air Oxidation		Off-site	Moderate Polish (Disposal)	Diss	<1 day								X					TEC	X		5.3	Typically used for waste water treatment.
Landfill		Off-site	(Disposal)	Neat Diss	Varies											X		TEC	X	$55-240/ ton	5.5	Requires containerization or dewatering. May require pretreatment and/or solidification.
Deepwell Injection		Off-site	(Disposal)	Neat Diss	Varies											X		TEC	X	$.06-$1/gal	5.6	Service generally contracted. Extensive geological study required to determine adequate well location.

Table 4C. Soluble Floaters (Continued)

Legend:

STE = Sanitary Egnineer
CHE = Chemical Engineer
CH = Chemist
HEO = Heavy Equipment Operator
PRO = Professional
TEC = Technician
NA = Not Applicable
CE = Civil Engineer
FR = Firefighter

Table 5C. Liquids on Land

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Barriers in Soil	C	In-situ	NA	Mixed	>1 day	(X)	(X)	(X)					(X)	(X)				PRO TEC	X		1.1.4	Soil Sealants must be applied to soil before hazardous material gets there. (X)= applies to some barriers
Chemically Active Covers	C	In-situ	Gross	Neat	Varies			X	X				X					CHE			1.2.2	No universal cover. Each spill must be evaluated on a case-by-case basis by a trained chemist.
Dikes, Berms, Dams	C	In-situ	NA	Neat Diss.	Varies		X	X			X							HEO CE		$\$4/\mathrm{yd}^3$	1.1.1	Earth moving equipment may require special access.
Foam Covers	C	In-situ	NA	Neat Diss.	<½ day	X	X	X					X	X		X		FR TEC		$\$5/$ gal spill	1.2.4	Very important to use foam which is chemically compatible with hazardous material.
Synthetic Membrane Liners	C	In-situ On-site	NA	Neat Diss.	Varies													TEC			1.2.3	Material must be chemically compatible with the hazardous substance.
Trenches	C	In-situ	NA	Neat Diss.	Varies		X	X			X		X					HEO CE		$\$.60\text{-}3.00/\mathrm{yd}^3$-land $\$5.\text{-}15./\mathrm{yd}^3$-water	1.1.2	
Dispersion/Dilution	D	In-situ	Gross	Neat Diss.	Varies							X							X		1.3.5	Bad weather may enhance dilution/dispersion. Type of hazardous substance dictates whether countermeasure is usable in populated areas.

Table 5C. Liquids on Land (Continued)

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	LIMITATIONS							REQUIREMENTS								Text Section	Comments
						Environmental																
						Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost		
Excavation	D	In-situ	Polish	Neat Mixed	Varies	X	X	X			X					X		HEO			1.3.2	
Pumping	D	In-situ	Gross	Neat Diss.	Varies			X			X		X	X		X				$50.-60/hr.	1.3.4	~32' height limit for vacuum pumping. May need explosion/corrosion proof pumps.
Biological Treatment	T	Off-site	Moderate-Polish	Diss.	>1 day								X					STE	X		4.0	May require special bacteria.
Biological Treatment	T	In-situ	Moderate-Polish	Diss.	>1 day			X										STE			4.0	May require special bacteria.
Cements	T	In-situ	NA	Neat	Varies											X		TTC			3.3.2	
Cements	T	Off-site	NA	Neat Diss.	Varies											X		TEC			3.3.2	Typically used to fix waste prior to burial in landfill.
Cryogenic Cooling	T	In-situ	NA	Neat Mixed	<½ day		X	X								X	X				2.2	With dry ice and LN_2 oxygen deficient atomosphere may result.
Evaporation	T	In-situ	Moderate-Polish	Neat Mixed	>1 day		X	X				X			X		X		X		2.5	Wind direction may preclude this countermeasure. Potential fire/toxic vapor hazard.
Extraction	T	On-site	Moderate	Mixed	>1 day						X		X	X	X	X		CH CHE TEC			3.2	Proper choice of solvent very important.
Gels	T	In-situ	NA	Neat	<½ day	X	X	X								X		TEC		$.50-2.50/lb	3.3.3	Avoid skin contact and inhalation. Low temperatures retard gelling time.
Hydrolysis	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X			CH CHE TEC			3.5	Reaction products may be hazardous. May require pre- & post- pH adjustment

Table 5C. Liquids on Land (Continued)

Page 3 of 4

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Incineration		On-site	Moderate-Polish (Disposal)	Neat Diss.	<1 day	X					X	X	X		X	X	X	PRO	X		5.2	May require stack monitoring. May produce toxic gas/ashes.
Incineration		Off-site	Moderate-Polish (Disposal)	Neat Diss.	<1 day								X		X	X	X	PRO	X	$395-791/ ton solid $53-237/ ton liq.	5.2	May require stack monitoring. May produce toxic gas/ashes.
Knockdown Spray	T	In-situ	NA	Vapor	<½ day	X	X	X						X				FR			2.9	Need to contain the hazardous runoff water.
Lime	T	In-situ	Gross	Neat Diss.	<½ day	X	X														3.3.4	
Natural Sorbents	T	In-situ	Gross	Neat	<1 day	X	X						X			X	X	TEC			2.1.2 2.1.3	May require use of dust masks. Special equipment may facilitate application.
Neutralization	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X		X	CH CHE TEC			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.
Neutralization	T	In-situ	Moderate-Polish	Diss.	<1 day	X	X								X		X	CH TEC			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.
Open Burning		In-situ On-site	Moderate-Polish	Neat Mixed	<1 day	X	X					X				X	X	FR	X		5.1	May produce toxic smoke. May require disposal of toxic ash.
Oxidation	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X		X	CH CHE TEC			3.7.1	Reducing/oxidizing agents and/or reaction products may be hazardous. pH adjustment may be necessary

Table 5C. Liquids on Land (Continued)

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Oxidation	T	In-situ	Moderate-Polish	Diss.	<1 day	X	X								X		X	CH TEC			3.7.1	Reducing/oxidizing agents and/or reaction products may be hazardous. pH adjustment may be necessary
Synthetic Sorbents	T	In-situ	Gross	Neat	<1 day	X	X						X			X	X	TEC			2.1.4	May require use of dust masks. Special equipment may facilitate application.
Vitrification		Off-site	NA	Solid	<1 day								X			X		PRO			5.7.1	Generally used to inhibit leachability of solids prior to burial.
Wet Air Oxidation		Off-site	Moderate-Polish (Disposal)	Diss.	<1 day								X					TEC	X		5.3	Typically used for industrial waste water treatment.
Landfill		Off-site	(Disposal)	Neat Mixed	Varies											X		TEC	X	$55-240/ton	5.5	May require containerization/solidification.
Deep Well Injection		Off-site	(Disposal)	Neat Mixed	Varies											X		TEC	X	$.06-1.00/gal.	5.6	Service generally contracted. Extensive geologic study to determine adquate well location.

Legend:

STE = Sanitary Engineer
CHE = Chemical Engineer
CH = Chemist
HEO = Heavy Equipment Operator
PRO = Professional
TEC = Technician
NA = Not Applicable
CE = Civil Engineer
FR = Firefighter

Table 6C. Particulate Solids on Land

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						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Water Covers	C	In-situ	NA	Neat	<½ day	X	X	X										FR TEC			1.2.6	
Synthetic Membrane Covers	C	In-situ	NA	Neat Mixed	Varies	X												TEC			1.2.3	Materials must be chemically compatible with the hazardous material.
Foam Covers	C	In-situ	NA	Neat Mixed	<½ day	X	X	X					X			X		FR TEC		$5/ gal spill	1.2.4	Foam must be chemically compatible with hazardous material.
Dispersion/Dilution	D	In-situ	Gross	Neat Mixed	<½ day							X						FR TEC	X		1.3.5	Type of hazardous material dictates whether ok in populated areas. May poison water treatment facilities if washed down drain
Excavation	D	In-situ	Polish	Neat Mixed	Varies	X	X				X					X		HFO CE			1.3.2	Earth moving equipment may require special access. Best for small spills.
Vacuuming	D	In-situ	Moderate-Polish	Neat Mixed	<½ day	X	X						X			X		TEC			1.3.6	May require vacuum cleaner designed specifically for hazardous material.
Biological Treatment		Off-site	Moderate-Polish	Mixed Diss.	>1 day								X					STE	X		4.0	May require special bacteria cultures.
Biological Treatment		In-situ	Moderate-Polish	Mixed Diss.	>1 day			X										STE			4.0	May require special bacteria cultures.
Extraction	T	On-site	Moderate	Mixed Diss.	>1 day						X		X	X	X	X		CH CHE TEC			3.2	Proper choice of solvent is very important.
Hydrolysis	T	On-site	Moderate-Polish	Diss.	>1 day						X		X	X	X			CH CHE TEC			3.5	Reaction products may be hazardous. May require pre- and post- pH adjustment.

Table 6C. Particulate Solids on Land (Continued)

						LIMITATIONS							REQUIREMENTS								
						Environmental															
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Incineration		On-site	Moderate-Polish (Disposal)	Neat Mixed Diss.	<1 day	X					X	X	X		X	X	X	PRO	X		5.2	May require stack monitoring. May produce toxic gases/ashes.
Incineration		Off-site	Moderate-Polish (Disposal)	Neat Mixed Diss.	<1 day								X		X	X	X	PRO	X	$325-791/ ton solid $53-237/ ton liq.	5.2	May require stack monitoring. May produce toxic gases/ashes.
Knockdown Spray	T	In-situ	NA	Vapor Dust	<½ day	X	X	X						X				FR			2.9	Need to contain the hazardous runoff water.
Oxidation	T	On-site	Moderate-Polish	Diss. Mixed	>1 day								X	X	X		X	CH CHE TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before and after reaction.
Oxidation	T	In-situ	Moderate-Polish	Diss. Mixed	<1 day	X	X								X		X	CH TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before and after reaction.
Pyrolysis		Off-site	(Disposal)	Diss.	<1 day								X								5.4	
Solidification/ Stabilization	T	In-situ On-site	NA	Diss. Mixed Neat	Varies		X									X		CH PRO TEC			3.3	Generally used to inhibit leachability of hazardous material prior to landfill.
Vitrification		Off-site	NA	Solid	<1 day								X			X		TEC			5.7.1	Generally used to inhibit leachability of solids prior to landfill.

Table 6C. Particulate Solids on Land (Continued)

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Wet Air Oxidation		Off-site	Moderate-Polish (Disposal)	Diss.	<1 day								X								5.3	Typically used for industrial waste water treatment.
Landfill		Off-site	(Disposal)	Neat Mixed	Varies											X		TFC	X		5.5	May require containerization/ solidification.

Legend:

STE = Sanitary Engineer
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PRO = Professional
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NA = Not Applicable
CE = Civil Engineer
FR = Firefighter

Table 7C. Gases Into Air

Page 1 of 1

						LIMITATIONS							REQUIREMENTS									
						Environmental																
Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Special Equipment	Power	Monitoring	Off-site Disposal/ Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Dikes, Trenches	C	In-situ	NA	Neat Diss.	Varies		X	X			X							HEO			1.1.1 1.1.2	Use to contain water if knockdown spray is used.
Foam Covers	C	In-situ	NA	Neat Diss.	<½ day	X	X	X					X			X		FR TEC		$5.00/ gal spill	1.2.5	Foam must be chemically compatible with hazardous material.
Patching, Plugging of Containers	C	In-situ	NA	Neat	<½ day		X	X									X	TEC			1.1.6	Requires working extremely close to the most hazardous zone.
Dispersion/Dilution	D	In-situ	Gross	Neat Diss. Vapor	Varies	X	X	X				X									1.3.5	Wind direction, type of hazardous material and spill size dictate whether this method is usable.
Cryogenic Cooling with CO_2/LN_2	T	In-situ	NA	Neat Diss.	<½ day	X	X	X	X	X	X					X	X	PRO TEC			2.2.1 2.2.2	Large tank trucks may require special access. Creates oxygen deficient atmospheres.
Cryogenic Cooling with water ice	T	In-situ	NA	Neat Diss.	<½ day	X	X	X	X	X								TEC			2.2.3	
Knockdown Spray	T	In-situ	NA	Vapor	<½ day	X	X	X						X				FR			2.9	Need to contain the hazardous runoff water.
Open Burning		In-situ	Moderate-Polish	Neat	<1 day	X	X										X	FR	X		5.1	May produce toxic smoke.

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SECTION 4

DESCRIPTION OF COUNTERMEASURES

This section presents brief descriptions and highlights the uses, requirements, and limitations of each of the release countermeasures listed in the "C" Tables beginning on page 103. The "text section" column for each countermeasure in the "C" Tables specifies the portion of Section 4 containing additional or supplemental information. The responder is urged to consult the relevant Section 4 material to extract information that will lead to usage of the countermeasure optimal for the release in question.

In general, Section 4 contains the following types of information:

- Description of the countermeasure
- Applicability of and recommendations for the countermeasure in field use
- Precautions in human and biota toxicity
- Limitations - environmental, demographic, and legal, e.g., permitting
- Requirements - power supply, manpower, and special equipment or supplies
- Availability of equipment and supplies
- Costs for both durable equipment and expendable supplies

Prior to final countermeasure selection the responder should take another look at the Site Assessment Checklist (Figure 3, page 9) to ascertain how the countermeasure impacts the environment or leads to adverse synergistic effects. Finally, if any further degree of refinement or detailed information on a specific countermeasure is required, reference sources are listed in the Bibliography, Section 5.

Table 8 gives a detailed table of contents for this section for the user's rapid reference.

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1.0 MECHANICAL CONTAINMENT AND DISPLACEMENT techniques either stop a release, immobilize or hinder the spread of a released hazardous substance without adding chemical reagents, or collect the hazardous substance or the contaminated soil, sediment, or water. An exception to this description is dispersion/dilution (Section 1.3.5), a voluntary action applicable to limited cases where containment or recovery is not feasible and the long-term threat is minimal. The mechanical countermeasures discussed below are generally followed by some form of treatment and, further, recovery.

1.1 Containment methods prevent the spread of a released hazardous substance by stopping or catching the release or by upstream diversion of a receiving stream. The path of the released hazardous substance may be blocked with barriers or diversions which are either preformed or constructed on site. Containment facilitates subsequent handling of the hazardous substance. Containment methods may include the following: dikes, berms and dams; trenches; booms; barriers in soil; stream diversion; patching and plugging of containers or vessels; portable catch basins; overpacked drums or other forms of containerization; and reorientation of the container. Each of these methods will be described in these sections to clarify the uses, requirements, and limitations specified in Tables B and C.

1.1.1 Dikes, Berms, and Dams.

Dikes, berms, and dams may be necessary to contain the spilled or spilling material on land or in water before effective collection can be initiated. Retention dikes and underflow dams may be used to contain floating insoluble materials; however, dike usage is limited to either containment of an entire water body or development of a diversion pathway. Dikes, berms, and dams may consist of earth, sediment, gravel, coarse sand, or polyurethane. Gravel and coarse sand are permeable materials that can be overlaid with relatively impermeable materials, such as clay.

Earth or sediment dikes or dams can be constructed using existing dredging equipment and/or earth-moving equipment such as bulldozers. Care should be taken when using large earth moving equipment in the presence of low flash point products. Gravel dikes require materials from quarries or a distributor; however, preference should be for materials from on-site, if at all possible, to minimize costs and time. Sand could be obtained from a distributor or be readily available if the spill occurs near the ocean. However, these retention dikes are confined to near-shore shallow-water areas. In-water dike construction has generally been conducted at depths of no more than 30 feet. Retention dikes often have sloped embankments constructed either in water or directly adjacent in bordering lowland areas and islands.

Foamed polyurethane can be generated on-site by use of a portable backpack system which can deliver a lightweight, rigid foam that is inert to many materials. Its primary drawback is its inability to obtain good adhesion on wet surfaces, which can greatly impact its effectiveness in water spills. Based on recent experiments, adhesion could be developed on wet concrete surfaces depending on the degree of wetness. On merely damp surfaces adhesion was considered as effective as on dry surfaces. Other considerations that may impact dike usage are as follows:

Costs: An emergency dike could be constructed of hydraulic fill for about $4/cu.yd. Thus a 20-foot-high dike with a 4:1 slope could cost at least $250/lin. ft., assuming no rip-rap, stone, or other material was used. Engineers' fees and contingency costs are additional.

Limitations: Retaining dikes are confined to near-shore, shallow-water areas. Polyurethane foams do not adhere to wet surfaces, although damp surfaces are as effective as dry surfaces. Polyurethane foams will be difficult to obtain in less populated areas.

Requirements: Manpower requirements are minimal --technicians and construction equipment (e.g., bulldozer) operators would be needed. Federal and/or state permits may be required, since partial or complete containment of the water body or mass may be necessary.

1.1.2 Trenches

Trenches or excavations are also a first step to contain a spilled material prior to treatment. They are effective and relatively inexpensive containment measures which can be used for landspills involving liquids and water spills involving insoluble sinkers.

Trenches on land generally require the use of large earth moving equipment such as bulldozers, and usually take advantage of natural conditions and slope to aid in collection of the spilled material. Trenches may also be constructed with small equipment or hand tools in some cases. Trenches are often used to contain the run-off when a knockdown spray (Section 2.9) is used to reduce vapor hazards associated with volatile liquids. Trenches used to contain volatile liquids will provide very little reduction in the evaporation rate.

Dredging equipment such as land-based clamshells, drag lines, and hydraulic and suction dredges are necessary for submerged trench construction to contain insoluble sinkers. Submerged trenches can also take advantage of any natural depression created by wave action or currents. However, it must be assumed that whatever forces created a natural depression might also remove the spilled material that tends to collect there. Excavation in water may also result in increased turbidity which would hinder further clean-up activities. No general rule exists for the size and placement of submerged trenches. If the current is flowing in one direction a downstream trench is indicated, but if currents are more or less random in direction then a trench encircling the spilled material is best.

Other factors that may influence the use of trenches for containment of spilled substances are as follows:

Limitations: Excavation of a submerged trench is only practical in water depths less than 50 feet. Wind, wave action and currents will also affect dredging operations. On land, soil and subsoil may render trenching ineffective or even impossible. It may be necessary to line the trenches with synthetic materials to prevent liquids from percolating into soft, porous soil (Sections 1.1.4 and 1.2.3).

Requirements: Heavy earth moving and/or dredging equipment. Soft ground or sediment. Heavy equipment operators and technicians necessary for land trench construction. Scuba or hard hat divers may be necessary for submerged trench construction. Special access required for both land and water excavations.

Costs: Excavation of trenches on land could be completed for approximately $0.60 to $3/cu.yd. depending on the size of the trench and type of soil. Costs for submerged trenches are considerably higher, somewhere between $5 to $15/cu.yd. If the current is flowing in one direction, a downstream trench would prove advantageous; if currents are more or less random in direction, then a trench encircling the spilled material would perhaps be best.

1.1.3 Booms

Booms are used to contain spills of hazardous materials in waterways. There are two general types of booms; surface booms and sealed booms or curtain barriers.

1.1.3.1 Surface Booms

Surface booms are used to contain water spills involving floating substances, including oil and hazardous materials. A primary concern is compatibility between the spilled substance and the boom material. The manufacturer should be consulted in all cases. If deployed rapidly, surface booms can also be used to contain any undissolved soluble floating substance. They are ineffective for containment of totally dispersed or sinking substances because commercially available surface booms have a draft of only 1 to 2 feet.

Surface booms can be placed downstream or downwind from a spill in order to catch and hold a hazardous substance as it is driven into the boom by the wind or current. They may also be used to totally encircle a spill or even to contain and displace a spill by dragging the booms holding the spilled material using boats. Most commercial booms are available in 50-100 foot sections which can be easily towed by boats and hooked together in order to protect large areas.

Limitations: Containment efficiency is affected by current, wind, and wave action. Generally ineffective if currents are greater than 1 knot and waves are greater than 2 to 4 feet. Compatibility with spilled hazardous material must be assured.

Requirements: May require special deployment equipment in addition to boats, e.g., winches, cranes. Also requires technicians experienced in deployment of booms.

Availability and Costs: Costs vary considerably but are typically $6/foot for off the shelf booms. Modification of a boom will raise the cost significantly. Surface booms are readily available from commercial vendors.

1.1.3.2 Curtain Barriers

Curtain barriers, sealed booms or silt barriers are used to contain hazardous materials that are soluble or sink in water. They are also used to control turbidity caused by dredging operation. When used with dredging, curtain barriers do not extend all the way to the bottom which makes them unsuitable for containing sinking hazardous substances. Curtain barriers have been designed for bottom to surface coverage. Barriers of flexible reinforced plastics have been developed for depths up to 25 feet. Buoyancy is provided by an air flotation collar.

Curtain barriers can assume the same configurations as surface booms, e.g., open (as in semicircle), closed, or maze-shaped.

Other factors which could influence the use and effectiveness of curtain barriers are:

Limitations: Applicability limited to waters with currents less than 2 knots and maximum depth of approximately 25 feet. Difficult to deploy in strong currents.

Requirements: Deployment of barriers may require up to five experienced technicians and several boats equipped with outboard motors. Auxiliary equipment such as pumps, winches, and compressors will vary depending upon type of barrier. Curtain material must be compatible with hazardous material.

Availability and Costs: Systems have been developed for the US Coast Guard and the EPA. These may not be commercially available. Costs of existing systems are between approximately $200 to $300/foot excluding auxiliary equipment.

1.1.4 Barriers in Soil

Barriers in soil are designed to prevent liquid hazardous substances from percolating into the soil and potentially contaminating the groundwater in the area around the spill. Several candidate methods are presented in this section: soil sealants applied directly to the surface soils or injected beneath the surface; slurry trenches developed around the perimeter of a spill; and sheet piling also around the perimeter of a spill to prevent further migration of contaminants or intrusion by groundwater.

1.1.4.1 Soil Sealants

The scenario for use of soil sealants is that they be applied immediately after a spill, preferably in the path of an advancing spill. Sealant/spill compatability should be verified prior to use. Sealants could also be used in conjunction with other containment measures such as dikes or trenches. Soil sealants and either dikes or trenches would, in conjunction, provide an adequate containment area for spilled material and, at the same time, eliminate most of the potential soil and groundwater contamination problems.

Soil surface sealants are generally grouped into three categories: reactive, nonreactive, and surface-chemical. Nonreactive sealants have previously been polymerized and are dispersed as an aqueous or solvent system. Common nonreactive sealants include bitumastic, rubber, polystyrene and polyvinyl chloride. Film formation of aqueous sealants is dependent both upon air velocity and temperature. Lower temperatures could result in slower film formation. Temperature is also an important factor in solvent based sealants.

Reactive sealants require two or more components to be mixed and reacted at the spill site. One component generally serves as a catalyst for the reaction. Included in this class are epoxy, urea/formaldehyde, and urethane sealants. These sealants are more likely to form a film under adverse weather, but they do have temperature limits.

Reactive sealants which form foams have the ability to effectively cover soil containing gravel and stones, in contrast to potential problems of "pinholes" and "shadowing" around coarse material when using nonreactive or nonfoaming reactive sealants.

Surface chemical sealants are generally repellents such as silicon and fluorocarbon systems. These sealants have been developed for textiles, paper, leather, and masonry. The most widely used materials are perfluoro derivatives of polyacrylates and are marketed as Scotchguard, Zepel, and the U.S. Army material Onarpel.

Sealants can also be injected into the soil, usually under pressure, to fill fractures and voids with stable insoluble materials. This process is commonly known as grouting. Grouts generally consist of either natural materials such as sands, clays, bentonite, and silts or various chemicals such as acrylomide, urea/formaldehyde resins, lignin, or silicate based materials. Cement is also used. In general, particulate grouts such as cement, bentonite etc., are used in coarse soils while chemical grouts are used in finer grained soils. Because most soils contain water, the potential for either desiccation or dissolution exists with the potential to form weak spots in the barrier.

Also, some chemical grouts themselves contain toxic substances which introduce the possiblity of long-term chronic toxicity. Successful grouting is both an art and a science, and should be undertaken only by someone experienced and knowledgable in this area.

Limitations: All forms of soil sealants are affected by extremes in temperature and precipitation. Composition of soil, both surface and subsurface, will determine whether a sealant will work effectively. It must be rapidly deployed, preferably in advance of the spill front, to prevent soil and groundwater contamination.

Requirements: A sealant delivery system is necessary. Surface sealant systems can range from a hand-held pump to a powered spray unit. Subsurface grouting requires a high-pressure injection system. Manpower should include trained technicians and supervision by a qualified engineer.

Availability and Costs: Soil sealants are readily available. Modification of off-the-shelf dispensing systems may be necessary before use. Costs were not available.

1.1.4.2 Slurry trenches

Slurry trenches provide a safe and relatively inexpensive method of installing groundwater barriers in unconsolidated soil materials. Draglines or backhoes are used to excavate a trench which is kept full of a bentonite-based fluid. This fluid develops a filter cake on the walls of the trench which reduces the seepage of fluid away from the excavation. It also exerts hydraulic pressure on the walls to help minimize caving. Using this process, excavations have been carried up to 100 feet in depth.

Once the excavation is complete it is normally backfilled with either concrete or some of the sand and coarser fractions of the excavated material. As the backfill material is pumped in, the bentonite slurry is displaced to the surface. The trench can be excavated in sections and as one section is backfilled, the dispaced slurry can be diverted into the next section of the trench.

The presence of organic and inorganic compounds in groundwater can have a detrimental affect on the bentonite slurry. Certain electrolytes and metals cause the slurry to flocculate and lose its ability to support the trench walls. Strong organic and inorganic acids and bases can dissolve aluminum and silicon components in the bentonite leading to a large increase in permeability.

In using the slurry trench method an experienced engineer should be consulted on the proper use and treatment of the slurry.

Other factors which could influence the use of slurry trenches for containment of hazardous materials are:

Limitations: The primary use of slurry trenches is as permanent, long-term groundwater barriers. Therefore, their use as an initial response containment is limited. Site topography, buried or overhead obstructions and limited access to the site may restrict use.

Requirements: Heavy equipment such as backhoe or dragline necessary for excavation. Careful study of soil conditions, permeabilities etc. should be performed in combination with net flow analysis in order to determine the best design. Manpower includes heavy equipment operators, experienced technicians and consulting engineers.

Costs: Costs (1979 prices) vary between \$2 and \$235 per sq. ft. depending on the composition of soil, excavation depth and the type of wall, either soil-bentonite or cement-bentonite.

1.1.4.3 Sheet Piling

Sheet piling is a commonly used method to establish a groundwater barrier. However, in some respects it is of questionable effectiveness. The interlocking of sheet piling does not give a completely water-tight seal and may have a relatively small effect in decreasing the flow of water.

Soil composition can also severely limit the effectiveness of sheet piling as a cut-off barrier. Boulders and cobbles may break the subsurface joints and divert the piles in a random manner below the surface so that little damming occurs. In some instances concrete piles may have to be set in preexcavated holes.

Limitations: Sheet piling is not suitable for short term, initial containment of hazardous materials. Site topography, buried obstructions, soil composition and limited access may restrict its use.

Requirements: Heavy equipment is necessary. Careful study of soil conditions and net flow analysis may be necessary in order to determine the best design. Manpower requirements include heavy equipment operators and a consulting engineer.

1.1.5 Stream Diversion

Stream diversion involves isolating a hazardous material spill by diverting the uncontaminated flow around the spill area. This is not a typical operation but could be accomplished by placing a dam, where possible, upstream of the impacted area, and then diverting the flow around the spill. Stream diversion is a potential countermeasure primarily when insoluble sinking hazardous substances are involved. The spill-impacted area will dry, thus facilitating cleanup of the hazardous materials.

Diversion of the uncontaminated flow can be accomplished, topography permitting, by a gravity bypass for stream flows less than 0.0063cu.m./sec (100 gpm). Pumping is necessary for streams with larger flows or where a combination of head and flowrate prohibit a gravity bypass.

EPA's Releases Control Branch (Edison, New Jersey) has developed a mobile stream diversion system with the capability of diverting a volume flow of 0.35cu.m./sec (5600 gpm) a distance of 0.3km, or lesser flow a distance of 0.9km. The entire system is engineered to fit a tractor-trailer rig or to allow for air shipment of the system.

Stream diversion is also feasible when soluble sinking or floating hazardous substance are involved. In a spill involving soluble substances rapid deployment and isolation of the entire spill-impacted area are necessary. Isolation of an entire water body can be accomplished in several ways each of which is dependent on volume flows, topography, site access etc. In situations involving low volume flow rates the stream could be dammed above and below the spill area, and the uncontaminated flow diverted around the newly formed pond.

Another possible technique is to construct a side excavation allowing the contaminated water to fill the excavation and then dam the inlet to prevent dispersion of the contained material. Also, a natural bend in a stream can be used to capture a spill by damming each end of the bend and diverting the uncontaminated flow.

Other factors which could influence the use of stream diversion as a containment measure are as follows:

Limitations: The stream volume flowrate cannot be too large. The EPA mobile system is limited to flowrates of less than 0.35cu.m./sec (5600 gpm). Topography of spill area must permit diversion, and suitable access for heavy equipment is necessary. Deployment of systems may take several days.

Requirements: Heavy earth moving equipment and pumping system. Pumping system will require auxiliary power such as electrical hookups or portable diesel generators.

1.1.6 Patching and Plugging of Container or Vessels

Patching and plugging of leaking containers should be one of the first procedures initiated when possible. Countermeasures to displace, treat, and dispose of hazardous materials already released at a spill site may require hours or even days to initiate and complete. Because of the time element involved in cleanup and the problems and hazards associated with treatment of large quantities of contaminated water or soil, it is vital to prevent further dissemination of the hazardous substance by stopping leaks.

Successful patching or plugging of leaks will depend upon several factors: the hazards in approaching the leaking container, the size of the hole, the hydraulic head, and the hazardous substance involved.

Potential sealants include epoxies, urethanes, Neoprene W, polysulfide rubber, putties, and instant foams contained in pressurized cylinders. In most cases some mechanical assistance will be necessary to support the patch while it hardens.

Other potential leak plugging systems include a self-contained expandable foam plug application system and an inflatable helicon bandaid. These systems, however, are not commercially available at this time.

1.1.7 Portable Collection Vessels

Portable collection vessels include any container or storage unit which can be easily transported to the site of a spill, assembled, and used to hold the hazardous substance, contaminated water, soil etc., either for further treatment or hauling. Typically, spilled liquid materials or contaminated water are pumped into the vessels. It is feasible in some cases to place a collection vessel immediately under a leak or rupture in a liquid storage unit and catch the substance as it leaks out.

Collecting vessels can vary from a portable swimming pool lined with a suitable resistant material to a manufactured synthetic tank into which liquids and flowable solids can be pumped under pressure. Portable tanks manufactured by Uniroyal are claimed to convert any type of open or closed truck, semi-trailer or van into a tank-truck by using their Sealed Tank containers.

Portable collection vessels are often used in conjunction with some other type of initial containment method such as diking or a lined trench. The spilled material is allowed to collect in the initial containment area and then displaced by pumping or excavating to a portable collection vessel. An Emergency Collection System for spilled hazardous materials was developed and designed for the EPA. This system consists of prepackaged pumping and storage for collection and temporary containment of a hazardous land spill. The storage unit consists of a prefabricated bag made from chemical-resistant, synthetic materials.

Limitations: The container material must be compatible with the hazardous material. In most cases a pumping system will be necessary in order to displace the hazardous material into the portable collection vessel.

Availability: Portable collection vessels are readily available off-the-shelf and range from portable swimming pools lined with a chemically resistant material to specially manufactured sealed tanks.

1.1.8 Overpacked Drums and Containerization

For spills from relatively small containers which have ruptured it is often possible to place the leaking container inside a larger specially designed container. Overpacking is a general term for this containment procedure.

Overpack drums are usually 85-gallon steel drums, lined with a chemically resistant synthetic material. Leaking containers are placed inside the overpack drum and sorbent materal is used to fill in the space between the container and the walls of the overpack. After filling, the overpack drum is sealed. If the leaking containers are small enough, several of them can be placed in one overpack drum in layers. Each container is protected from the one above or below it by a layer of sorbent material. It is absolutely necessary that the contents of the overpack stay securely in place and are not allowed to shift inside the drum.

Extreme care must be exercised to ensure that combustible or explosive gases do not form inside the overpack so that drum explosions are avoided. In an actual incident, ruptured 30-gal drums containing phosphorus were placed in 55-gal overpack drums filled with sand and water. One of the sealed overpack drums subsequently exploded and injured six people.

Limitations: The size of a ruptured container may be too large to make overpacking feasible. Personnel must be able to approach and handle the leaking containers.

Requirements: Overpack drums of suitable size, synthetic liner, sorbent material. Often forklifts or other devices capable of lifting relatively heavy loads are necessary to lift ruptured containers and place them into the overpack. If drums are to be disposed of at a hazardous landfill, certain overpack criteria and standards must be adhered to.

Availability: Due to widespread use overpack drums and sorbent material should be readily available.

1.1.9 Reorientation of Container

Often the simplest and most effective countermeasures are overlooked. Among these is reorientation of the ruptured vessel. Leaking containers can often be rotated, placed in an upright position, or otherwise reoriented in order to prevent any remaining hazardous material from escaping.

Limitations for the use of this countermeasure include 1) the rupture in the vessel is not too large to prevent reorienting it effectively, 2) personnel can safely approach the spill site and handle the materials. Reorientation may require heavy equipment such as a crane or forklift in order to reposition the container.

1.2 Covering and lining techniques serve to contain hazardous substances on the surface. Certain types of covers and liners are used in the construction of permitted waste disposal sites. Other cover materials provide temporary mitigation of airborne hazards. Candidate techniques and materials are discussed in the following section.

1.2.1 *In Situ* Burial/Encapsulation

In situ burial/encapsulation techniques have been suggested as a potential response to water spills involving insoluble sinking solids. It must be stressed however, that burial in waterways is not recommended and is chosen only by default. It is an uncertain procedure that may be defeated by erosion caused by bottom currents and tides. As a permanent containment countermeasure burial would only be acceptable when the spilled material is so innocuous that redispersion by currents would not significantly endanger the environment. Thus most material suitable for burial would have to be so safe that burial is unnecessary. Certain inorganic solids could conceivably be buried permanently. Liquids are inappropriate due to the tendency to disperse, and organic solids should be considered too toxic to be allowed to remain in the environment. Appropriate situations where underwater burial/encapsulation might be considered are:

- Temporary mitigating measure to retard dispersion or reduce hazard until dredging/removal can begin.
- Final step after dredging operations, to isolate any residual contaminated sediment.
- Sole response when recovery is not feasible or when material is harmless.

Burial on land has been used as a temporary measure to help mitigate hazardous vapors and prevent entrainment of particulate material into the atmosphere. Under no circumstances should *in situ* burial be considered as a permanent response to a hazardous material spill. Burial in a permitted landfill as an ultimate disposal method is discussed in Section 5.5.

There are many potential materials which can be used for burial/encapsulation: clays, sands, diatomaceous earth, dredged sediment or excavated soil, asphalt cement and various chemical grouts such as furfural and its derivatives, lignosulfite derivatives, phenoplasts, polyacrylamids, and silica gels. It must be kept in mind that many chemical grouts contain materials considered to be hazardous. Chemically active materials such as gypsum and lime and certain pozzolans such as fly ash may be selectively used to neutralize certain hazardous substances.

Limitations: Temporary mitigation or containment of spills on land only. Burial in water hampered by current, turbulence and elevated water temperatures. Burial of a vessel containing a gas could lead to explosion and is not recommended.

Requirements: Underwater burial will require dispensing equipment such as a hopper dredge or hydraulic pumpdown apparatus. Burial on land will require heavy equipment such as bulldozer, backhoe etc.

Availability and Costs: Inert materials such as dredged sediment, excavated soils, sand, clay etc., are readily available and inexpensive. Off-shelf chemical grouts, however, may take several days to obtain.

1.2.2 Chemically Active Covers

A covering material is considered to be chemically active if it will readily react with the spilled compound to neutralize or otherwise decrease its inherent toxicity. When employing an active cover, each spilled material must be considered on a case-by-case basis as there are no universal active covering materials. Because of this fact, each spill should be evaluated by a chemist familiar with the spilled material and its chemistry.

As with *in situ* burial/encapsulation, covering a spill with a chemically active cover is only a temporary mitigation response. The materials should not be allowed to remain in the environment except for the possible condition discussed in the previous section.

Candidate materials for use as chemically active covers include scrap iron, sulfide ores-pyrite, clays, diatomaceous earth, manganese dioxide, proteinaceous wastes such as wool, carbon compounds such as activated carbon (see Section 2.1.1), bonechar, calcium carbonates such as lime, limestone and chalk, gypsum, sulfur, potassium permanganate, alum, alumina, ferric sulfate, and certain commercial ion exchanges resins. The active mechanisms of these materials include sorption, ion exchange, oxidation, and neutralization. Discussion of these countermeasures are given in other sections.

Limitation: Cover materials depend on the specific hazardous material to be treated. There are no universal covers.

Availability and Costs: Many of the materials listed above are readily available. Price not included here, but see section discussing specific mechanism.

1.2.3 Synthetic Membrane Covers/Liners

Synthetic membrane materials such as Dupont Hypalon, PVC, polypropylene, chlorinated polyethylene, butyl rubber, ethylene polypropylene diene monomer, and hydrocarbon resistant PVC serve as linings for oxidation ponds, evaporation ponds, tanks, aeration ponds, waste treatment ponds, etc. These materials are also used to cover solid waste heaps and slag heaps to prevent entrainment of dust or water.

The chemical resistivity, variety, and availability of these materials makes them ideally suited for use in hazardous materials spill mitigation. Use of these materials applies to all landspills involving liquids and solids. They serve as liners for containment and treatment ponds, and soil sediments in spills involving liquids. Also, they cover spills involving solids in order to prevent reentrainment of the particulates. In certain cases synthetic materials could be used to cover spills involving volatile liquids in order to reduce hazardous vapors.

The use of synthetic covers on a landspill is limited to relatively small spills which can be safely approached by clean-up personnel. Application of covers to large areas without direct contact by the clean-up crew with the hazardous material is, at best, very difficult. Synthetic membranes can be readily purchased, however, in sheets up to 85 feet in width and 400 to 600 feet in length.

These materials also can cover insoluble sinking materials in water as a temporary containment measure. A cover could be placed over spilled material in order to immobilize it or otherwise keep it from dispersing until it can be removed. Several factors, though, severly limit the use of synthetic covers in water spills. Among these are logistics, equipment, water current and depth, and bottom contour. It is also applicable only to non-navigable or shallow waters.

Synthetic membrane materials are resistant to a wide variety of hazardous substances; however, chemical compatibility and permeation should be determined before use. The manufacturer should be consulted before using a particular membrane material with a particular hazardous substance or treatment process. Also, certain treatment countermeasures involve extremely exothermic reactions, e.g. neutralization. It is critical, therefore, that the liner for the treatment pond, bank, etc., is able to withstand elevated temperatures. Otherwise, the synthetic material may become severely weakened or melt. It is highly recommended that treatment or containment ponds are double-lined with a layer of inert material such as sand (approximately 1 foot) between the liners. This gives added protection in case the inside liner should melt or rupture.

1.2.4 Foam Covers

Foam covers are used as a vapor reduction measure and will not actually contain a spill. Foam covers should be used in conjunction with other containment countermeasures. Foams provide temporary mitigation of threats to air quality by acting as a barrier to ignition and evaporation.

Soft foam systems may utilize (1) protein extracts or natural surfactants, or 2) synthetic surfactants. In these water-based foams the surfactants lower the surface tension of the foam below that of the spilled material, so that the foam spreads out as a film over the hazardous liquid. Protein base foams are typically low expansion (expansion is the ratio of expanded foam volume to volume of foam solution) and are usually formed by mechanical agitation. Surfactant foams, on the other hand, are typically high expansion and are generated by impacting the foam solution on a screen or net. The air flow necessary to produce high expansion foams is provided by a fan or water spray aspiration. The use of high expansion foams is recommended for longer term vapor control (up to several hours, depending upon the hazardous material). Also, in general, the thicker the foam layer, the longer it takes the vapor to break through and reach the lower explosive limit (LEL) above the foam cover. For all types of foams however, reapplication is recommended every 30 to 60 minutes.

Even as vapor control agents, conventional foams are not applicable for use on hazardous materials with 1) low boiling points, 2) reactivity in the presence of water, resulting in heat generation or pH changes, or 3) high corrosion, radioactivity, or explosiveness. Ammonia is a worst case example of a material which is incompatible with conventional, water-based foams due to exothermic reaction with water, alkalinity, and low boiling point.

Special foams have been developed for use on compounds such as ammonia, but they may not be readily available on short notice. Among these are acrysols, a class of acid type polymers which form a solid gel when neutralized by a base. Foams have also been developed which are more effective on low molecular weight, volatile, highly polar solvents such as alcohols, ketones, etc. Among these are the silicate systems, consisting of a commercial grade water system containing approximately 30% dissolved sodium silicate, and pectin type foams prepared using an aqueous solution of pure citrus pectin. In fact, pectin foams have an exceptional ability to minimize the evaporation of a number of substances including polar and nonpolar compounds. It is important to remember that even though the use of foam is well documented for hydrocarbon fires, one should not assume that a foam will work with every type of hazardous material. For more information on foams, the user is alerted to a foam use guidelines document to be issued by ASTM Committee F-20 on Hazardous Substances and Oil Spill Response.

Other factors which could influence the use of foam covers as a vapor control measure follow.

Limitations: Foams must be compatible with the specific hazardous material involved in the spill. Foams are generally limited to nonpolar compounds and those which have a pH close to neutral. Foams are susceptible to "lifting" and drift both during and after application. Precipitation will reduce the effectiveness of foam covers. Current and wave action limit the use of foam covers on floating spills to quiescent water.

Availability and Costs: Conventional fire fighting foams and application equipment should be readily available. Costs of equipment and material required to place a 16 inch layer of high expansion foam over a spill of 10,000 gallons of a floating hazardous material are estimated to be $50,000 (1975 $).

1.2.5 Inert Gas Blankets

Inert, heavier-than-air gases can be utilized as a vapor control countermeasure. Primarily limited to the use of CO_2, the inert gas settles over the top of a spilled material and inhibits its evaporation. The use of CO_2 blankets with hydrocarbon spills is documented. Lighter-than-air inert gases such as nitrogen can also be used, but an additional cover or tent of a synthetic material would be necessary to keep the gas in contact with the surface of the spill.

Inert gas covers are often an additional benefit resulting from the use of either solid CO_2 or liquid nitrogen for cryogenic cooling of a spill. The most likely scenario for use of a gas cover would be to first contain the spill behind a dike or in trench and then use the inert gas to trap the hazardous vapors in the trench.

1.2.6 Water Covers

Water covers provide an effective vapor control measure if the spilled material is denser than water or if the spilled material is soluble in water. Water covers reduce evaporation and also the water can be used to herd the spilled material into locations suitable for clean-up. Application of water to a spill either as a cover or as a solute should only be attempted on small spills where a dike has been constructed in order to contain the water/hazardous substance(s) mixture. Under no circumstances should the mixture be allowed to flow into nearby water courses or into a sewer system. Do not attempt to apply water to substances such as alkali metals or other water reactive compounds as explosion and/or emission of flammable or poisonous gases could result.

It is necessary to have water pumping equipment and heavy equipment available. The heavy equipment is used to construct dikes or trenches around the spills. Local fire department personnel should be consulted and can often provide the necessary personnel and pumping equipment. Since this is a vapor control procedure, treatment of the spilled hazardous substance and the water used to cover the spill is still needed.

1.3 Displacement: Displacement techniques are mechanical methods for the relocation of the hazardous substance on the contaminated soil, sediment, or water. The specific displacement techniques which will be covered in this section are hydraulic and mechanical dredging, excavation, skimming, pumping, dispersion/dilution, and vacuuming.

1.3.1 Dredging

Dredging involves four tasks; 1) loosening or dislodging sediment by mechanically penetrating, grabbing, raking, cutting, drilling, blasting or hydraulic scouring; 2) a lift action accomplished by mechanical devices such as buckets or by hydraulic suction; 3) the transport of dredged materials by pipeline, scows, hopper dredges or trucks; and 4) disposal of the dredged material.

Dredges are categorized by the basic means of dislodging the sediment (mechanical or hydraulic), the device used to excavate the sediment (cutterhead, dustpan or plain suction), and the pumping device (centrifugal, pneumatic or airlift, e.g.).

The type of equipment and methods to be employed are based upon several practical considerations among which are: 1) type and amount of sediment to be dredged, 2) physical and hydrologic characteristics of the dredging site, 3) disposal considerations, and 4) availability of equipment.

Additional factors to be considered because of hazards are the need for precise determination of the contaminated zone, very precise lateral and vertical control of the dredging head, and the need for complete containment, transport and treatment/destruction prior to disposal to minimize damage to aquatic and benthic organisms including the effects of resuspension of the spilled substance.

1.3.1.1 Hydraulic Dredging

Hydraulic dredges, including plain suction, dustpan cutter head and hopper dredge remove and transport sediments in liquid slurry form using diesel or electric powered hydraulic pumps with discharge pipes. Slurries containing 10 to 20 percent solids by weight are normally transported through pontoon-supported pipelines for distances up to several thousand meters.

The plain suction dredge uses plain suction to entrain a water-sediment mixture and is limited to free-flowing sediments. It would be quite efficient for use against intact masses of liquid or granular solid chemicals. Dustpan dredges use high pressure water jets around the edge of the flared dredging head to loosen sediment and create a slurry. This type of dredge often causes relatively high turbidity in the dredged area. Cutterhead dredges employ a rotating mechanical digging apparatus to loosen hard material and generate a slurry. While hydraulic dredges are capable of very high production rates (in excess of 10,000 cu yd per hour for a 48 in. diameter pipeline) they tend to be cumbersome as they rely on anchors, cables, and winches to move them across the work site.

A small hydraulic dredge, known as the Mudcat, is readily available in the United States from the National Car Rental Agency. The Mudcat can dredge a swath eight feet wide by eighteen inches thick in water as shallow as 19 inches and as deep as 15 feet. The Mudcat has been tested in a hazardous material clean-up role and seems well suited to small cleaning jobs.

Problems associated with hydraulic dredges include:

- Suitable collection (in basins), proper treatment and disposal of dredge spoil, and water must be provided.
- Clogging of suction head or lines by mud, debris, etc. This can be minimized by the use of an auger on the suction head.
- Controlling suction head in order to prevent burial in mud, or high liquid-to-solid pickup.
- Pump scows can cause resuspension of settled solids in sedimentation tanks. The problem can generally be eliminated by placing an equalization tank upstream from the sedimentation tank and other treatment processess.

Other factors which could influence the use of hydraulic dredges as a viable displacement technique follow.

Limitations: Dustpan and Mudcat dredges are not designed to operate in open waters. The Mudcat limit is 15 feet water depth. Most dredges are limited by wave and current action, generally maximum wave height is 1 to 3 ft and maximum current is 3 to 5 knots.

Requirements: Will require personnel experienced in operation of dredging equipment. Divers may be necessary in order to locate and mark off perimeter of spill. Processing and treatment tanks will be necessary in order to remove suspended solids and treat water.

Availability and Costs: Most dustpan and cutter head dredges are owned by the Army Corps of Engineers and may not be readily available. Mudcat dredging and other small handheld hydraulic dredges are readily available. Estimated dredging costs are $5.00/cu yd of material removed for both the dustpan and Mudcat dredges.

1.3.1.2 Mechanical Dredging

Mechanical dredges such as clamshell and dipper dredges, remove bottom sediment through the direct application of mechanical force to dislodge, excavate, and bring to the surface material at almost *in situ* densities. Most mechanical dredges deposit the dredged material into scows or barges for transportation to a disposal site. Excavation rates vary up to a maximum of about 500 cu.yd. per hour.

The main disadvantages of mechanical dredges are 1) high turbidity caused by resuspension of sediment during the hoisting process, and 2) ineffectiveness against free liquid contaminant on bottom. The major advantage is the ability to work in relatively close quarters and around structures, obstacles, and debris.

Also, the clamshell is limited to excavation, to approximately 150 feet in water.

Additional information is provided below.

Limitations: Limited to spills of solid material which cover relatively small areas. Wave and currents will affect dredges. Generally, maximum wave heights are 1-3 feet and maximum currents are 3-5 knots.

Requirements: Will require means to transport and dispose of sediment. Will require personnel experienced in operation of dredging equipment. Divers may be necessary in order to locate and mark off perimeter of spill.

Costs: Estimated dredging costs using a clamshell dredge, not including disposal of sediment is $15 per cu yd of sediment.

1.3.2 Excavation

Excavation is a mechanical displacement technique for removing the source of the pollution. Contaminated soils and earth materials are excavated using conventional construction equipment such as backhoes, draglines, front end loaders, and even shovels. The removal of drums is more complex and usually involves the use of specialized drum handling equipment such as backhoe mounted drum grapplers. The type and size of the spill will determine the type of equipment necessary to effect a satisfactory cleanup. Generally, excavation should be considered for 1) small spills involving less toxic wastes, 2) where a high hazard to drinking water supplies exists, 3) where insoluble wastes cannot be removed by pumping alone or 4) where long-term treatment would be too costly. Excavation of the contaminated soils is the first step in the clean-up process. The contaminated materials must be properly disposed of. Disposal could involve hauling to an approved hazardous waste dump site, incineration on- or off-site, or some other treatment technique such as solidification, encapsulation, or solvent extraction and drying. Solidification of excavated materials can ultimately lead to reduced disposal costs if the solidified waste can be considered non-hazardous (after laboratory tests).

Excavation is ineffective as a total removal technique if the contaminants have already leached from the spill site. Soil types, ground and surface waters, and amount of precipitation after a spill are all factors which can influence the degree to which a material has leached. Excavation of all contaminated substances (including groundwater and the strata through which it flows) is rarely performed due to the high costs associated with the transport and treatment or disposal of large volumes of soil.

When excavation is the preferred and optimum removal method the following factors must be considered:

- Determine extent of contamination.
- Establish a strict safety program; do not overlook potential for toxic and ignitable fumes.
- Utilize adequate protective clothing and equipment as needed.
- Provide suitable measures to move contaminated soils from the excavation site to the transporting equipment.
- Locate approved dumpsite to accept material once excavated or decide upon some other feasible disposal or treatment technique.

Costs involved will vary depending upon size of spill and hence, the type of equipment necessary. Costs range anywhere from approximately $0.50 to $25.00 per cu yd, the latter for manual excavation. Hauling costs are approximately $1.00 to $2.50 per mile per cu yd. All of the above costs include equipment and labor charges.

1.3.3 Skimming

Skimmers are used to remove liquids floating on the water surface. Skimmers may be divided into four functional classes: moving plane skimmers, belt skimmers, weir skimmers, and suction head skimmers. Weir and suction skimmers typically remove both water and floating liquids. Reservoirs are provided to separate the liquids and dispose of the water. Most skimmers were designed for oil collection and may have plastic parts (e.g., PVC hoses) which are incompatible with many hazardous materials. It is also important to note that when using skimmers with flammable spills, the motors and other electrical equipment must be explosion-proof. The principles of operation and range of application for each class of skimmer are discussed in the following paragraphs.

Moving Plane Skimmers. Moving plane skimmers operate by means of a flat pickup element that is dipped into the hazardous substance slick. The element is then withdrawn and the adhering hazardous substance is wiped off into a reservoir. This type of skimmer was designed for viscous oil skimming and is not suitable for low-viscosity substances.

Belt Skimmers. Belt skimmers employ an adsorbent belt to collect the spill. The belt may lift the hazardous substance out of the water to a reservoir or, in some designs, may move downward, pulling the substance under water where it floats up into a reservoir. Some units will also pick up loose sorbents.

Weir Skimmers. Weir skimmers consist of a collecting reservoir, the lip of which is below the surface of the hazardous substance. The substance flows by gravity over the lip and into the collection reservoir where it is removed by an onboard pump or through a suction hose to a remote pump. The lip height is adjustable to accommodate varying slick thicknesses. Weir skimmers are generally unsuitable for sorbent harvesting because of the screens used to keep out debris. Weir skimmers work best in calm water.

Suction Head Skimmers. Suction head skimmers are very similar to weir skimmers. The primary difference between the suction head and weir skimmer is that the suction head skimmer draws the hazardous substance through a hose as soon as it flows over the weir into the suction head and then collects in a reservoir. In a weir skimmer the hazardous substance is collected in a reservoir first.

1.3.4 Pumping

Pumping spilled materials into a holding truck or other container is most applicable to small spills of hazardous liquid materials on land. The spilled materials are commonly diverted into a trench or some other type of excavation from which they are pumped into a container such as a vacuum truck. The spilled material may also have to be pumped out of the container for disposal. Pumping also proves very useful in removing accumulated pools of flammable materials, thus reducing the potential of a large fire if it is ignited.

It is also feasible to use pumping as a removal technique for water spills of both solid and liquid hazardous materials. It would be most applicable to spills involving relatively insoluble floating materials. But, if pumps can be deployed rapidly, any undissolved soluble floating material could also be removed. Pumping could also be employed to remove insoluble sinking materials. In this case divers using hand-held devices could locate pockets or pools of settled material and pump them into a container either on-shore or on a boat. A considerable volume of water will also be pumped; this must be treated before disposal.

An important fact to remember when considering vacuum pumping as a displacement technique is that it is not possible to displace a water column more than 32 feet vertically by vacuum pumping. This fact places special restrictions on the use of vacuum technique in terms of access to the spill, water depth etc. The use of multistage centrifugal or positive-displacement pumps would be more practical since they may be used to any depth. Also the pumping equipment, whether centrifugal, positive displacement, vacuum, etc., must be compatible with the hazardous material and may require special corrosion resistant lines and explosion proof pumps.

Pumping costs will vary depending upon the type of hazardous material which is to be pumped, the amount of material, and the distance between the spill site and the disposal site. Generally, charges for vacuum pumping range from $50 to $60/hour. Disposal costs are not included in this figure. Vacuum pumping services are readily available, and most are organized to quickly respond to emergency spills.

1.3.5 Dispersion/Dilution

Dispersion/dilution is a process which faclitates dilution of a hazardous substance released into water or on land by promoting suspension of the hazardous substance.

Dilution of spills on land is generally carried out using water sprayed onto the spill. The main interest in diluting land spills is usually to reduce the vapor hazards associated with the spill. The area around the spills should always be diked in order to prevent runoff from entering nearby water ways, sewers, etc. Under no circumstances should a hazardous substance spill on land merely be dispersed using water.

In the case of spills into water, dispersion should not be considered a first-choice response, however, because of the potential toxic effects on aquatic biota. Careful examination of the specific spill situation and the potential toxic effects must be conducted prior to use. If other methods of containment and subsequent treatment are available, they should be employed.

The principle behind the use of dispersion in the case of a spill into water is to spread the spilled material out over a large area in order to reduce the concentration of the hazardous material to below recommended limits. The use of a dispersion technique will accomplish this in a relatively short period of time and within a relatively short transport distance from the spill site. In the case of some organic pollutants, such as oil, this could facilitate an increase in the biodegradation rate. Typical scenarios where dispersion might be considered appropriate include:

- o Open water where dispersion will result in rapid dilution of the spilled material.
- o In small streams flowing into larger rivers.
- o At the mouth of a harbor which experiences fast tidal currents.

The use of any dispersion technique carries with it the requirement to carefully monitor the immediate aquatic environment. Of critical importance is measurement of increase in biological oxygen demand (BOD). Biological stress would generally be expected if the percentage of oxygen saturation decreased to approximately 50% (4.6 mg/l).

Dispersion of a spilled hazardous material can be accomplished in several ways, predominately through mechanical and chemical means. These two methods are discussed briefly below.

1.3.5.1 Mechanical

Depending upon the size and location of the spill, a number of mechanical dispersion devices are readily available. Water streams, from a fire hose could be relatively effective in rather shallow waters and with small spills. Propwash from a boat could also be used. The use of compressed air, in conjunction with commercially available lagoon aeration systems could be used to disperse selected materials from the bottom of water bodies.

As a last resort, flow augmentation, probably useful in small streams flowing into larger rivers, would also be used. This would consist of using water stored upstream to wash the spill into the larger water body. However, this method would be partially dependent on the availability of a means of predicting duration of toxic concentration, flow rates, etc., for the receiving, larger water body.

1.3.5.2 Chemical

Chemical dispersion facilitates the dilution of a hazardous substance through the use of surfactants. Surfactants function to reduce the surface tension of the water, causing organic liquids to spread out in a thin layer over the surface of the water body. This, in turn, increases the surface area available to attachment by microorganisms.

Application of chemical dispersants is generally accomplished using hand-operated pumps and pressure systems, portable pump eductor systems, spray booms, and aerial spray methods. Mixing, possibly using the propwash of a surface workboat, may be necessary to aid is dispersion, though self-mix dispersants are available.

Again, it should be noted that the use of dispersion should not be considered a first-choice response. Dispersion for hazardous materials should be considered as a last resort. The use of dispersants must be subject to decisions on a case-by-case basis. The ultimate decision would depend on environmental conditions at the site, the amount of hazardous material spilled, the material's toxicity, and similar considerations.

1.3.6 Vacuuming

Vacuuming is used to clean up spills involving small quantities of dry particulates and fine dusts. (Vacuum pumping of large liquid spills is discussed under Section 1.3.4.) Certain small commercial vacuums, generally designed for cleanup of small spills in laboratories, are equipped with multistage filter systems designed to remove particles and dust from the air before returning it to the atmosphere. The vacuum systems designed for laboratory use have small capacity (about 0.1 to 1.0 cu. ft.) and are not suitable for large spills. These small units generally sell for between $500 - $1000 and can also be rented. Rental costs were not available. Large truck-mounted vacuum systems (approximately 150 - 650 cu.ft. capacity) are available from certain spill cleanup firms on a contract or rental basis for cleanup of large spills. Costs associated with these units are generally $80 to $90/hour. This cost does not include disposal of the material. Care should be taken with flammable materials containing dust or vapor. Vapor problems will be increased by air flow in vacuuming.

2.0 PHYSICAL TREATMENT processes allow separation of materials, the hazardous substance and the contaminated medium, without chemically transforming or binding the hazardous substance and without adding chemical reagents.

2.1 Adsorption is a surface phenomenom which separates a hazardous liquid from a bulk, nonhazardous liquid like water by contact with a solid adsorbent. Typical adsorbents are materials, which have small, interconnected interstices or pores that are wetted by the liquid, and to which the liquid clings primarily by surface forces and capillary action. Available information indicates that adsorbents would be of value for treatment of all land spills and of water spills of some organic materials. Use of adsorbents for treatment of water spills will be limited, in most cases, to those substances that are insoluble and float on the water surface.

Adsorbents are divided into two general types: natural and synthetic. Natural adsorbents consist of natural products such as cellulose, minerals, and rubber. Synthetic products are made from various organic polymers such as polyurethane, polypropylene, and macroreticular resins, molecular zeolite sieves, and amorphous silicates. This section will describe natural and synthetic adsorbents with their limitations and use requirements and identify durable and expendable costs, if available.

2.1.1. Activated Carbon

Activated carbon adsorption is a physical phenomenon which removes organic and some inorganic chemicals from water. These chemicals are physically adsorbed on the surface of the carbon (typically 500-1000 m^2/gram). Carbon adsorption should be given serious consideration when it is desirable to remove mixed organics from water, to remove select inorganics from water, or in special cases to recover select organics or inorganics from aqueous solution. Activated carbon can be produced from various materials including wood, coal, peat, and lignin. These are prepared using dehydration and carbonization, followed by activation to enlarge the pore openings, which increases the surface area and therefore increases the adsorptive capacity. Activated carbon is considered relatively nontoxic in field situations. Based on available evidence, the application of activated carbon alone to water bodies will not constitute a threat to human or aquatic life unless applied in massive quantities.

The adsorption process is dependent on the nature of the material being adsorbed, the solution concentration and the carbon used for adsorption. Critical factors include molecular size and polarity, type of carbon, pH of the solution, carbon contact time and solubility of the contaminant. The adsorption rate decreases with increasing temperature and decreasing concentrations. In general, activated carbon is cost-effective when used to remove moderate to low concentration organic substances in water. Higher concentrations may produce large amounts of spent carbon. The amount of carbon needed to adsorb a certain chemical must be established by actual testing. Various tests can be used, but these should be done on the contaminant in its natural environment since other constituents of the medium may also exert a carbon "demand".

Extensive information is available as to the activity of various charcoals, and a great many methods have been developed for applying the adsorbents applicable to the water system in which a mixed spill of a hazardous chemical exists. Examples of these are fixed beds or columns, and carbon-filled "tea bags," through which the contaminated water may be brought into intimate contact with the adsorbent.

Because of its general off-the-shelf availablity, versatility, and applicability, activated carbon is the chemical agent of highest overall value for present-day use in amelioration of spills of low level hazardous chemicals on water.

It is perhaps the only practical adsorbent immediately available in quantity for pentadecanol, ethyl ether, n-amyl alcohol, bromine, chloroform, and nitrobenzene, if the sorbent is to be used for amelioration of spills on water.

Additional information on activated carbon is briefly listed below.

Form: Powders, granules, rods, and sheets.

Availability: Due to widespread use, activated carbon should be available within 1 day.

Costs: Activated carbon cost ranges from $0.50 to $5.00/lb.

Activated carbon is available in both granular (GAC) and powdered (PAC) form. A brief description of each form of activated carbon and advantages and disadvantages is given herein.

2.1.1.1. Granular Activated Carbon

Granular carbon adsorbs pollutants less rapidly than powdered carbon; however, its coarse grain size permits greater flexibility in the design of dispersal and retrieval techniques. One of the first concepts considered for water spill cleanup operations was a carbon-filled porous cloth "tea bag." In using the tea bag, a certain amount of agitation is necessary to increase the pollution removal rate. Natural wave action in a lake may not be adequate for ventilation of the carbon-filled tea bags. However, GAC is also used in fixed beds or columns. It is the predominant form of activated carbon used in water spill cleanup operations and industrial waste treatment.

Additional considerations that may impact GAC usage are as follows:

Limitations: In using the carbon-filled porous cloth tea bags, measured agitation is necessary for removal of the hazardous substance from surface water. Therefore, usage of the GAC in strong winds or in rough or very calm water conditions is not recommended.

Regeneration: Carbon adsorption systems, especially those employing thermal regeneration, are generally considered to involve both high capital and high operating costs. The process economics achievable with thermal reactivation of the carbon (on site) may only be realized if carbon usage is above 5000 lbs/day and the treatment system is of a permanent nature. Below this cutoff point it is more economical to purchase new carbon or to use the services of a centralized reactivation facility.

Availability: Granular activated carbon is generally available in most areas.

Manpower: Manpower requirements are minimal--technicians and unskilled laborers would be qualified.

2.1.1.2. Powdered Activated Carbon (PAC)

Powdered carbon is less expensive than granular carbon and has a slightly higher adsorption capacity, but it suffers from three primary drawbacks: (1) it is difficult to regenerate (without high losses); (2) it is difficult to handle (the settling characteristics may be poor); and (3) in the presence of suspended solids coagulation may occur (since powdered carbon is a coagulant). Free powdered carbon is not suitable for use in natural waters except as a last resort or where the pollutant-laden powder would settle to the bottom where it could be located and removed.

Currently, there are no full-scale applications of industrial waste treatment incorporating powdered carbon suitable in water spills. Therefore, PAC use in hazardous substance spills in water is limited.

2.1.2 Natural Organic Adsorbents

Natural organic adsorbents consist of natural products such as cellulose - vegetable and wood fiber - and other products such as rubber. Natural materials have been used for years in mitigating oil spills. However, complete data are not available on their effectiveness for adsorbing other organic liquids. Removal of oil-soaked or other organic-soaked natural adsorbent is imperative for effective spill treatment. Often these materials are treated to obtain or enhance their hydrophobic characteristics. Natural adsorbents are less expensive and generally more cost-effective than synthetic polymers.

Cellulose fibers consist of such materials as wood fiber, corn cobs, fiber board, straw, sawdust, bark, peanut hulls, peat moss, and exotics like Kapok. It is known that natural adsorbents (such as straw and corn cobs) and other types of cellulose fibers will adsorb oil and perhaps similar organics from surfaces having thick floating deposits. Desorption from these materials is known to be significant; thus it may be concluded that sorbate retention is poor.

Adsorbent materials derived from natural materials are presumed to be nontoxic, though confirming data are not available. A large amount of these materials introduced into a water body could produce a high biological oxygen demand (BOC) upon degradation by microorganisms. Slowly degradable substances such as lignin-based materials or sawdust, would not be expected to impose as rapid a biological oxygen demand as straw or other highly biodegradable organics. Additional information on cellulose adsorbent forms, availability, costs, limitations, and manpower requirements are listed below.

Forms: These materials are available in particulate form, and may be available as pillow sorbents, as well as booms.

Availability: The primary advantage of using cellulose fibers for adsorption is availability. These materials can often be easily obtained in isolated rural and urban areas, possibly subject to seasonal considerations. They are, however, usually water specific.

Costs: Natural organic adsorbents are considered the least expensive of the adsorbents. The costs range between $0.01 and $0.02 per pound.

Limitations: Application of particulate adsorbents is not recommended during windy conditions, any type of precipitation (e.g., rain or snow), or when water conditions are flowing, choppy, or agitated. These materials are recommended for use on land spills and on insoluble floating spills in relatively undisturbed water.

Manpower Requirements: Technicians and unskilled laborers can be effectively utilized in cellulose adsorbent application and collection of the used adsorbent.

2.1.3 Natural Inorganic Adsorbents

Inorganic natural materials that can be used as adsorbents include clays (Florida, Georgia, Tennessee, and Western clays), deatomaceous earth, Fullers earth, perlite, vermiculite, expanded shale and natural zeolite. Other materials can include spent lime, calcium carbonate, and rock wool. Mineral adsorbents can be used to adsorb various types of hydrocarbons, acids and derivatives, alcohols, aldehydes and ketones, esters and nitrogen compounds. Clays adsorb like zeolites, that is they adsorb either ions or molecules and can adsorb selectively by size as well as by polarity or electrical charge. Zeolites have a crystalline structure that contains empty channels of atomic, ionic, or molecular dimensions; however, clays have adsorption channels that are interstitial between polysilicate sheets that are forced apart by the sorbate in a swelling action. Adsorbent clays have been used for adsorption in a variety of large-scale separations. Clays are used solely for land spills; however, clay application for cleanup of a hazardous substance in water was used for removal of phenol from an effluent. Additional information on mineral adsorbents is provided below.

Forms: The majority of these inorganic materials are only available as particulate adsorbents.

Limitations: Application of particulate adsorbents is not recommended during (1) windy conditions, and (2) precipitation. Clays are not recommended for any type of water spills, with the exception of phenol.

Manpower Requirements: Technicians and unskilled laborers can effectively apply and harvest the sorbent.

Costs: Natural inorganic adsorbents - untreated - are inexpensive. The costs range between \$0.01 and \$0.02 per pound. Treated minerals have a cost range of \$0.30 to \$0.40 per pound.

2.1.4 Synthetic Adsorbents

Synthetic adsorbents, expecially organic polymers, have been specifically manufactured to adsorb organic liquids while repelling water. Since they were designed for organic material, it is not expected that these adsorbents are efficient in the adsorption of inorganic liquids.

Current information on synthetic product adsorption is for pure organic liquids. Thus synthetic adsorbent products are effective for land spills of pure organic liquids and for highly insoluble organic liquids that float on the water surface. As a general rule, it appears that polar substances with appreciable solubility or miscibility with water are rated as poorly removed by synthetic adsorbents. Most synthetic adsorbents, with the notable exception of imbiber beads, only loosely adsorb oil and other organic liquids. Wringing or squeezing the adsorbed organics from the synthetic adsorbents for reuse is claimed to be logistically advantageous, as well as cost effective.

A description of various properties, limitations, and requirements for polyurethane, polypropylene, and macroreticular resins is given within this subsection.

2.1.4.1 Polyurethane

Polyurethane polymer can be produced in open pore, closed pore, and nonporous particulate form. All of the forms adsorb a variety of chemicals from aqueous systems, but the open pore form also adsorbs liquids like a sponge. The adsorption action depends on the openness of the pore structure and its connectivity, and also upon the viscosity and wetting power of the sorbate for polyurethane. Polyurethane is not as versatile as activated carbon, but the art of using it for spill amelioration of floating hazardous chemicals, especially regeneratively and continuously, is more advanced. Polyurethane can be formed on-site or even *in situ*. It can be shredded on site, used in belts, and broadcast by a blower over a spill. Scrap polyurethane foam, which is generally available and cheaper than new open market or custom-produced material, may also be of some use in amelioration. The potential hazard of residual polyurethane (due to floatability loss) can be reduced in two ways: (1) by providing closed as well as open pores in the matrix, and (2) laminating a thin sheet of close pore polyurethane to a thick web of open pore polyurethane with a polyurethane adhesive. Additional information on polyurethane fiber is provided below.

Forms: Shredded foam and foam in the form of belts, mats, pollows, and sheets.

Regeneration: Yes, a marked advantage of using polyurethane versus natural adsorbents; however, not usually used for major spills or for spills of highly toxic substances.

Availability: Generally available, mostly in larger metropolitan areas.

Manpower Requirements: Technicians are capable of handling application, collection, and recycling of polyurethane at a hazardous spill cleanup operation. Technicians must be careful when handling the recycling of contaminated polyurethane since the contaminated polyurethane may be flammable or toxic.

2.1.4.2. Polypropylene

Polypropylene is a linear hydrocarbon polymer that is inherently oleophilic and thus an adsorbent for nonpolar liquids or solutes. It is considered somewhat less versatile in range than the polyurethanes. The means employed for collecting and reusing polyurethane should apply to polypropylene.

Polypropylenes of higher average molecular weight and crystallinity have better solvent and chemical resistance. Such improved resistance widens their applicability, but may make formulation or fabrication more difficult or more costly for certain methods of application. Byproduct polypropylene and recycled polypropylene are commonly cheaper than new polymers of the same type and grade. Polypropylene tailored to specifications or delivered in unusual forms is often much more expensive. Scrap polypropylene is sometimes usable with little loss of performance capability.

Form: Belts, mats, pillows, and sheets (no shredded foam).

Regeneration: Yes, an advantage of polypropylene adsorbents over natural adsorbents; however, not usually used for major spills or for spills of highly toxic substances.

Availability: Available mostly in metropolitan areas.

Manpower Requirements: Technicians are capable of handling application, collection, and recycling of polypropylene.

2.1.4.3 Macroreticular Resins

Two common macroreticular polymers are polystyrene (co-polymerized with divinylbenzene) and polymethyl methacrylate (co-polymerized with ethylene dimethacrylate). Ionic groups can be reacted with these resins. Thus macroreticular resins can exhibit not only adsorption characteristics, but also ion exchange characteristics.

Regeneration capabilities are possible. Desorption by heating is not possible for organic resin sorbents because of their thermal sensitivity to bond cleavage and oxidation. Additional information on macroreticular resin forms for field use, regeneration properties, and availability is given below.

Form: Particulate.

Regeneration: Not feasible for field use. Air stream, eluent, and vacuum desorption are considered viable regeneration possibilities.

Availability: Primary producers are Rohm and Haas, Union Carbide, Diamond Shamrock, and Dow Chemical.

Manpower Requirements: Technicians are capable of handling application and collection, once given instructions on the operations of the ion exchanger.

2.2 Cryogenic Cooling is a technique for reducing the evaporation of spilled hazardous materials, diminishing both the toxicity and flammability hazards. Deployment of the technique consists of distributing a cryogen (usually ice, liquid nitrogen or dry ice) over the surface of the spill. Alternatively, leaking containers can be packed in the cooling medium. In addition to the primary effect of reducing the vapor pressure of the hazardous substance, cryogenic cooling can, in many cases, immobilize a liquid spill by freezing it. Also, the use of dry ice creates an inert gas blanket which prevents the ignition of flammable substances.

The efficiency of cryogenic cooling to ameliorate spills of hazardous chemicals is controlled by four factors: delivery, physical properties of the spilled chemical, the freezing point of water, and environmental factors.

Delivery of the cryogenic material affects the ultimate efficiency of this technique. It is imperative that the cryogen be spread evenly, over as large an area as possible and very quickly. Overall vaporization rate reductions will be directly proportional to the efficiency with which a homogeneous cooling blanket of cryogen is placed over the spill.

Physical properties of the spilled substance can have an effect on the efficiency of the technique, which will be related to the effect of temperature on viscosity, vapor pressure and rate of vaporization. These effects are small compared to the others and can generally be ignored.

The presence of a large excess of water, as in a spill into a body of water, limits the achievable final temperature to 32° F (0° C), the freezing point of water. In spite of this, vapor pressures can be reduced by 40 to 95% if the final temperature is maintained at the ice point.

Environmental factors, such as rain, wind, and water turbulence, are just as important in this spill response technique as in others.

Warm days with bright sunshine will impose a higher surface heat load. Rain, wind, and waves not only increase the heat load by mixing, but also disturb the inert gas blanket.

The choice of the cryogenic medium determines the effectiveness of this response technique, as well as the environmental impacts. The following sections describe the specific characteristics of cooling by carbon dioxide, liquid nitrogen, and wet ice.

Consideration must be given to the influence of the cryogenic medium or coolant on other concurrent or subsequent countermeasures. The extent to which cooling may interfere with other steps must be considered.

2.2.1 Carbon dioxide

Carbon dioxide, or CO_2, is available in liquid or solid form. Liquid carbon dioxide is supplied in pressurized bottles or in large capacity tanks which require refrigeration systems to reliquefy the boil-off. Solid CO_2, commonly known as dry ice, is sold in block form. Since the blocks are not stored in gas-tight containers, evaporation losses during shipment can be significant.

Solid and liquid CO_2 require different application techniques. Expansion nozzles known as snow horns are available from Airco for converting liquid CO_2 to solid CO_2 snow at high (42 to 45% by weight) efficiencies. Largest standard horns have a capacity of 42 lb/min of snow, using 100 lb/min of liquid CO_2. Equipment is required for dispersing the generated snow over the spill area and adds to the system cost. This could be a conventional snow blower, modified for cryogenic service, using stainless steel contacting parts. Operation would require 2 to 3 persons. Electrical power is required for storage refrigeration. Standby maintenance is minimal.

CO_2 in solid form must be crushed and broadcast over the spill using a snow thrower or mulch spreader. Special materials of construction may be required to withstand the cryogenic temperature of dry ice. Taking into account the refrigeration capacity lost during application, dry ice is more cost effective as a cryogen than liquid CO_2.

Several advantages of liquid CO_2 over liquid nitrogen (LN_2) have been cited:

- Loss-free storage is possible since CO_2 tanks are equipped with gas recycling systems.

- CO_2 tanks are single-walled in contrast to the double-walled vacuum insulated tanks used for LN_2. This makes CO_2 tanks less costly and more resistant to the "high-g" stresses experienced aboard ships.

- CO_2 costs less than LN_2, based on equivalent effective refrigeration expected during spill response.

- CO_2 dispersal is easier to effect since "snow horns" (described above) are available for small applications. Modifications for large application areas may be feasible using such methods as: positioning booms for standard snow horns; a snow lance at the perimeter to create a snowstorm (at some loss in transfer efficiency); blowers to broadcast the snow horn feed directly or indirectly using a water spray heat transfer medium to broadcast a mixture of wet/dry ice.

There are two potential problems posed by the use of CO_2. Although it is non-toxic, the use of large quantities of CO_2 may produce an unbreathable oxygen deficient atmosphere resulting in an additional safety hazard to personnel. This danger is amplified by the tendency of CO_2 to settle and accumulate in depressions. Moreover, CO_2 added to water decreases the pH and may adversely affect the aquatic biota.

2.2.2 Liquid Nitrogen

The temperature of liquid nitrogen (LN_2) is much lower than that of dry ice. Almost all volatile hazardous substances (except hydrogen) freeze at LN_2 temperature and the vapor pressures are reduced to insignificant levels. LN_2 does not present a danger to the aquatic environment as does CO_2.

Efficient application of liquid nitrogen is difficult. Spraying would vaporize all LN_2 within a few feet from the nozzle. Pouring it directly over the spill surface would result in slow spreading over the locally formed ice plates. The LN_2 would stay and boil off these plates with excessive cooling at the point of application. Accounting for cooling losses during application, the effective refrigeration efficiency of LN_2 is far less than that of CO_2, especially solid CO_2. Furthermore, there is potential danger of the LN_2 boiling explosively upon application.

It should be emphasized that under no circumstances is liquefied air to be used in place of LN_2 for spill response. The nitrogen boils away preferentially, leaving behind extremely hazardous concentrations of liquid oxygen which could react with an oxidizable organic material.

2.2.3 Wet Ice

Wet ice can be used as a cooling medium in hazardous spill response. The primary advantages are its low cost, ready availability, and capability of being generated at the spill site. In addition, it is easily distributed with very little loss of cooling capacity.

One main disadvantage is that, unlike CO_2 and LN_2, wet ice does not evaporate away. Instead it melts and increases the volume of contaminated medium to be treated or disposed of. The fact that it is not as cold as dry ice or LN_2 is not as disadvantageous as one might think, at least in water spills. As mentioned earlier, the final temperature achievable in a spill where a large excess of water is present is 32° F regardless of the temperature of the cryogen employed. Caution: check to see that material does not react with water.

2.3 Granular media filtration is a physical separation process that removes solids from aqueous suspensions. The suspended particles are removed from the liquid by forcing the mixture through a series of particulate media. Granular media filtration is one of the most widely used methods for separating solids from wastewater. Specific applications include removal of chemical floc, such as heavy metal precipitates, following precipitation, and removal of biological floc in settled effluent from secondary treatment of sanitary wastewater. It is most advantageous following some form of precipitation, flocculation, and/or sedimentation and may serve as an intermediate step preceding carbon adsorption or ion exchange, or as a final polishing technique.

Granular media filtration systems generally include porous filter media, induced pressure differential (gravity, positive pressure, vacuum), a tower or column to contain the filter media and direct influent and effluent flows, and a method to remove contained solids from the filtration media (typically a backwash system). Critical operating parameters such as loading and backwash rates, filter media and depth are critical to successful operation of a filtration system. The filtration media are often layers of sand, gravel, coal, or other particulate materials in series.

Granular media filters over a period of use will plug up with solids and require backflushing to remove the entrained material. Backflush water is generally 1 to 4% the volume of the original filtrate and thus the solids percentage is concentrated. The backflush waste will require disposal. Often backflush water is allowed to settle and is then recycled through the filtration system.

Granular media filtration systems generally operate at capacities of 2 to 6 gallons per minute/sq. ft.

2.4 Gravity separation is a physical separation process that takes advantage of differences in specific gravity of the various components of a liquid mixture. Typical units involve flotation or sedimentation, but centrifugal-force-driven separation is included. Gravity separation units function to increase the solids concentration in a fraction of the liquid's original volume, or to differentiate a mixture of liquids with different specific gravities. Gravity separation is usually preceded and/or followed by other treatment processes. Successful application of gravity separation techniques requires careful scale-up from treatability test data. Several candidate gravity separation methods exist including flotation, sedimentation, centrifuges, and hydrocyclones, the latter of which is in reality a type of centrifuge.

2.4.1 Flotation

The term flotation has two meanings. One meaning applies to materials that are less dense than water and thus will float on the surface. No chemical treatment or mechanized methods are necessary to cause these materials to float and thus they are more easily removed.

Flotation also refers to a physical-chemical method widely used in ore processing for concentrating finely ground ores. This process involves chemical treatment of an ore slurry to create conditions conducive to the attachment of selected mineral particles to air bubbles forming the slurry. The air bubbles carry the mineral to the surface where they are skimmed off. Thus materials heavier than water are made to float for easier removal. Even though the technology is well understood, costs generally make it prohibitive for waste treatment.

One exception to this is the EPA's mobile froth flotation unit originally designed to remove oil from beach sand following an oil spill. Compressed air pumped into flotation chambers creates a froth containing the oil on the surface. Skimmers are then employed to remove the froth. This system has also been used successfully to remove free or loosely bound creosote from contaminated river water before further treatment.

2.4.2 Sedimentation

Sedimentation is a necessary step following precipitation or coagulation but can also be used prior to chemical treatment to remove insoluble sinking substances. Sedimentation tanks can be set up on-site and consist of three main components: tank, influent well, and sludge baffle. Tanks are generally open top pools constructed of heavy gauge vinyl or other similar materials. A sand base is generally placed under the pools. A 55-gallon drum can serve as an influent well to reduce the influent velocity and protect the sludge layer. The sludge baffle provides an area from which to drain the clarified liquid out of the tank without removing settled sludge.

2.4.3 Centrifugation

This is a physical process which separates the components of a fluid by the application of centrifugal force. It is analogous to sedimentation but applies forces many times greater than gravity by mechanical means. Thus it is more effective in separating components with small differences in density. Centrifugation is most applicable to dewatering sludge and has high potential for the removal of solids from hazardous slurries or sludges. Centrifugation is not normally used for colloidal suspensions. The clarified liquid is generally treated further as if it contains suspended solids. Costs for in-plant installations are estimated to be \$20 to \$45/ton of processed dry solids (1978 \$).

2.4.4 Hydrocyclone

Hydrocyclones are, in a manner of speaking, a type of centrifuge without moving parts. Suspended solids are separated from the fluid by centrifugal force caused by rotation of the fluid in a cone assembly. Usually the rotation is effected by tangential fluid entry into the cone. The heavier particles settle to the bottom of the cone while the higher clarified effluent moves toward the center vortex and exits through an overflow outlet. Hydrocyclones are employed during dredging operations and are located before sedimentation tanks in order to prevent an excessive build-up of solids in the tanks. Hydrocyclone units of all sizes are commercially available. Tests of hydrocyclone units indicate that they would only be appropriate for removal of contaminants held on particles of sand size, 74 microns or larger.

2.5 Evaporation as an industrial process is well-defined and well established. It is used currently for the treatment of hazardous waste, such as radioactive liquids and for sludges, concentrated plating, paint solvents, and other wastes. Often steam or direct firing is used as a heat source to increase the rate of evaporation. The most economical method of evaporation is by using solar evaporation ponds. This method offers the benefit of photolytic decomposition of organic wastes that degrade with exposure to ultraviolet light.

Evaporation in situ should be considered a feasible response only under the following conditions:

- Spill is in a remote, inaccessible area
- Volume of spill is relatively small
- Other countermeasures are not feasible.

Great care must be taken with hazardous volatiles which include high-vapor-pressure chemicals (those boiling at ambient temperature and pressure) and cryogens (those boiling below ambient temperature and pressure). An extremely flammable and/or toxic atmosphere could develop over the spill, so that continuous air monitoring is necessary to determine the extent and duration of any vapor hazard. The vapors formed by spills of most cryogens generally will dissipate over time, however.

Several environmental factors affect the rate of evaporation, including air temperature, wind turbulence, and in the case of spills in water, water temperature and the ratio of the volume of material spilled to the area of the water body. The wind speed and wind direction must also be considered. Even though the actual spill location may be removed from any population, air currents could carry the vapors toward populated areas.

2.6 Magnetic separation is applicable only to the removal of magnetic and non-magnetic particles from liquid streams. A waste stream is fed into a magnetic field where magnetic particles are collected on filters, generally woven steel fabric or compressed steel wool. The magnetic field is then shut off, and the collected waste material is washed from the filter bed.

Magnetic separators designed for field use are available, most notably the Dynactor. Soluble, non-magnetic contaminants can often be removed from a waste stream by first using powdered activated carbon to adsorb the contaminants. The carbon suspension is then thickened by the formation of a magnetic floc when the proper amounts of magnetic material are mixed with the carbon in the presence of a polyelectrolite flocculating agent such as aluminum sulfate ($Al_2(SO_4)_3$). Magnetite (Fe_3O_4) is a commonly used magnetic material.

2.7 Membrane separation is a physical process utilizing a preferentially permeable membrane to separate components of a solution or suspension. The driving forces of membrane separation processes are pressure differential or concentration gradient. The most widely used processes include dialysis, reverse osmosis, and ultrafiltration. Dialysis produces a waste stream requiring additional concentration for disposal and for this reason has little utility for hazardous waste treatment. Reverse osmosis and ultrafiltration are discussed below.

2.7.1 Reverse Osmosis

Reverse osmosis uses high pressure to force a solvent (e.g., water) through a membrane that is permeable to the solvent molecules but not to the solute molecules. It is used primarily in industrial applications to demineralize brackish waters and to treat a variety of industrial waste waters.

Compact reverse osmosis units are commercially available, can be started easily and shut down relatively quickly, can be serviced conveniently, would produce only a small volume of residue (10 to 25% of the feed), would not require skilled labor, and can be operated with electric power produced on-site. Thus reverse osmosis meets many of the requirements of a mobile system. However, a significant amount of time may be required to obtain and assemble the necessary components. Another major shortcoming is membrane susceptibility to fouling or degradation caused by the presence of suspended solids or strong oxidizers in the wastewater or very low pH wastewaters. For this reason, pretreatment of the waste stream e.g., coagulation/flocculation, is necessary before treatment by reverse osmosis. Depending upon the specific waste to be treated and the type of membrane used, reverse osmosis is generally used as a final polishing step. One final consideration is that a certain amount of concentrated waste material will require further treatment or disposal. Additional information concerning reverse osmosis is given below.

Limitations: Variability in flow or chemical characteristics in feed streams represent substantial complications for membrane technologies. Power consumption is also a significant factor.

Requirements: Operation of a 227,000 l/day (60,000 gal/day) mobile unit would require site access, electrical power, and a minimum of two technicans working 6-12 hours per 24 hours.

Applicability: Test units can be rented to make the evaluation of applicability in a laboratory. A small volume of wastewater is processed through test units containing commercial membranes. During these tests, permeate waters are collected as successive small fractions, and are analyzed for pollutants of concern. The concentrated solutions are also analyzed. If the pollutant concentration in the desired permeate fraction is less than the effluent limitation, then the membrane process will be applicable.

Cost: Capital cost for a 227,000 l/day (60,000 gal/day) mobile reverse osmosis system and support equipment has been estimated to be $70,000 (1981 $).

2.7.2 Ultrafiltration

Ultrafiltration is a pressure-driven membrane separation process that operates at a lower pressure than reverse osmosis and is suitable for applications involving larger molecules. Ultrafiltration is suitable for removal of heavy metals and organics. Several types of membranes and membrane systems are commercially available. Most full scale uses of ultrafiltration to date have been in industrial operations such as concentrated cheese whey, dye rinses, and emulsified oils. Ultrafiltration has been tested with waste streams containing solid concentrations up to 46,300 ppm. However, when used with high concentration waste streams, the effluent may require additional treatment or disposal. Ultrafiltration units produce a waste concentrate which is 10-25% of the feed water volume. This concentrate must either be treated or disposed of a a permitted landfill.

Ultrafiltration systems are not available in mobile units for field use, although vendors have skid-mounted units that can be installed on a trailer for transport to spill locations. These units typically consist of one or two modules with water flux capacities in the 18,900 - 39,800 l/day (5,000 to 10,000 gal/day) range.

Additional information is given below.

Limitations: Primary limitations of ultrafiltration systems include their inapplicability to wastes containing low molecular weight substances and their inability to produce low concentration permeates from highly concentrated wastes. Variability in flow or chemical characteristics in feed streams and power consumption are also factors that limit application of membrane technologies.

Requirements: Operation of a 227,000 l/day mobile unit will require site access, electrical power, and a minimum of two technicians working 6-12 hours per 24 hours.

Costs: Estimated capital costs of a 227,000 l/day mobile system has been estimated to be $35,000 (1981 $).

2.8 Stripping is a physical diffusion process which separates gases or volatile components from aqueous waste streams by mechanically increasing the air/liquid or steam/liquid surface area, thus permitting a greater rate of diffusion than quiescent conditions would allow. Candidate processes are discussed below.

2.8.1 Aeration

Air stripping or aeration removes volatile compounds in aqueous solutions by increasing the air/liquid interface area. The increased contact area is produced by mechanical means such as in-stream aeration with compressed air, spraying the aqueous solution into the air, and agitating the surface. Aeration lagoon systems at muncipal wastewater treatment facilities commonly use the latter two techniques. For field situations surface agitation and in-stream aeration are probably the most viable. In-stream aeration can be accomplished using cylinders of compressed air, or perforated pipes attached to an on-shore compressor. Surface agitation can be accomplished in several ways including outboard-motor prop wash and water streams from fire hoses. Air stripping using a basin or tank and air sparging or mechanical aeration can be both practical and cost effective for removal of contaminants. Access to the spill site and availability of the necessary equipment, however, must be considered. *In situ* aeration is a very feasible treatment method, and air stripping using packed towers or even cooling towers may also be effective.

The application of aeration to the removal of volatile components from aqueous solutions is critically dependent on the potential environmental impact of the resulting air emissions. As with evaporation, aeration could produce toxic fumes and therefore should be considered for small spills in remote areas. Also, continuous air monitoring during the aeration process must be conducted. Another limitation to the use of aeration is that often, in order to be effective, the pH of the contaminated aqueous solution must be adjusted. The ambient air and water temperatures, and wind speed and direction are factors which must be considered.

2.8.2 Steam Stripping

Steam stripping is essentially an absorption process used to remove volatile components from aqueous solutions. The output from a steam stripping unit is a concentrated vapor and a very dilute treated stream. The concentrated vapor containing the steam-stripped volatiles can either be recycled or incinerated. Current applications include the recovery of ammonia from coke oven gas, and the recovery of light chlorinated hydrocarbons from wastewaters. Steam stripping is applicable to the removal of volatile compounds from wastewater either as a pretreatment prior to land application or in direct discharge. Steam stripping system components include reboilers, packed columns or tray towers, feed tanks, pumps, and a steam source. The system is energy intensive.

Additional information is given below.

Limitations: Use of steam stripping requires a source of steam; however, steam supplies may be unavailable on-site. Steam stripping is thus not suitable for emergency field use unless the contaminated aqueous solution can be transported from the spill site to a steam stripping facility.

Costs: The treatment cost for a 1,230 l/min (300 gal/min) facility has been estimated to be about $1.80 per 100 liters (1981 $). This estimate includes capital expenditures, and labor, overhead and other expenses.

2.9 Knockdown spray or spraying a water fog can be used to effectively reduce water soluble hazardous gas or vapor concentrations in the atmosphere by entrainment and precipitation. Often, as is the case with ammonia, the vapor is water soluble. The primary use of a water fog is, therefore, to protect personnel in the spill area, and the public in the vicinity, from potentially lethal vapors. Water fogs also serve to cool ruptured containers and to flush released substances from contaminated surfaces. The runoff from the knockdown spray must be contained using dikes, trenches, or some other scheme in order to prevent contamination of nearby streams or runoff from entering sewers. The runoff will necessarily have to be treated or properly disposed of.

3.0 CHEMICAL TREATMENT processes separate components of a hazardous substance mixture by chemically transforming the hazardous substance by the addition of reactive chemicals.

Chemical treatment can be performed either in the field or at a waste processing facility. In order to qualify as an ultimate disposal method, the treatment should convert the spilled hazardous material to innocuous end products. In situ chemical treatment processes must be carefully controlled and contained as, in some cases, the chemical treatment agent can pose an equal or greater potential hazard to the environment than the original pollutant. The following section discusses several chemical treatment processes.

3.1 Coagulation/Flocculation is a nondestructive separation process by which small particles suspended in a liquid are made to agglomerate into larger particles. In this process, the repulsive electrostatic and interionic forces which keep the particles suspended are overcome by mixing chemical coagulants so that gravitational and inertial forces will cause sedimentation of the flocculated mass.

Tests are recommended in order to determine the optimum coagulating/flocculating agent to be used and the correct concentration of the agent. Since the contaminants may be unknown, trial and error is often used. A common sequence of such tests is:

1. Initial settling of untreated waste (if any)
2. Addition of agent accompanied by rapid mixing
3. Slow mixing to allow coagulation/flocculation
4. Sedimentation of floc
5. Filtration to determine amount of sediment.

The primary parameters being measured during a test are:

- Degree to which substance will precipitate, along with reaction time and required agent dosage
- Type of agents used and the time required to flocculate
- Settling rate of floc
- Final volume of sludge produced

Various coagulating/flocculating agents are available for clarifying organic and inorganic suspensions. The most common and readily available agents include iron salts such as ferric chloride ($FeCl_3$), alum (aluminum sulfate, $Al_2(SO_4)_3$), and polyelectrolytes. The need for controlled conditions necessitates treatment in tanks, etc., rather than *in situ*. Coagulation/flocculation is also non-selective and nondestructive which means that the resulting sludge will be hazardous and must be collected and disposed of properly. A brief description on the use of each of these agents follows.

3.1.1 Ferric Chloride

The final pH of the waste stream to be treated should be above 6.0 for best results, so lime or caustic soda may be needed to adjust pH. Dilute suspensions require dosages of 50 to 500 mg/l, although larger doses may be needed for concentrated suspension. Excessive doses will result in brown-colored effluent and should be avoided.

Availability: Ferric chloride is readily available in dry or liquid form. Liquid ferric chloride is a dark brown oily, corrosive solution available in 5 to 13 gallon carboys, 3,000 to 4,000 gallon bulk truckload lots, or 4,000-10,000 gallon carloads.

Limitations: Ferric chloride is an extremely corrosive material which must be stored and transported in special, corrosion resistant containers. Dosages are not stoichiometric and must be rechecked frequently via jar tests. Dry ferric chloride must be dissolved before use.

3.1.2 Alum

The waste stream pH should be between 6.5 to 7.5 for optimum results and may require the addition of lime or caustic soda for pH control. Dilute suspensions require dosages of 100 to 1000 mg/l, whereas huge doses may be required for concentrated or highly alkaline solutions.

Available: Alum, a white crystal, is supplied in lumps or in ground, rice, or powdered form. Shipments may be in small bags (100 lbs), in drums, or bulk quantities (over 40,000 lbs). Liquid solutions up to 50% alum are also available in minimum loads of 4,000 gallons.

Limitations: Alum solution is corrosive. Approximate dosages are not stoichiometric and must be rechecked frequently. Alum sludge is voluminous and is difficult to dewater.

3.1.3 Polyelectrolytes

Polyelectrolytes are available in anionic or cationic form and may be used alone or in conjunction with another agent. Polyelectrolytes may be effective alone for inorganic solutions such as metal salts, but they are generally not effective alone for organic suspensions. They are effective for organic suspensions when they are used with alum or ferric chloride. Cationic polyelectrolytes are generally added in higher dosages, [1 to 10 mg/l, for dilute suspensions (<100 mg/l suspended solids) or up to 100 mg/l for concentrated suspensions] than anionic species.

Availability: Polyelectrolytes are readily available in dry or liquid form. Dry polymers are supplied in relatively small quantities (<100 lb bags or barrels). Many competing polymer formulations with differing characteristics are available, requiring somewhat differing handling procedures. Manufacturers should be consulted for optimum practices.

Limitations: Stock polymers solutions may be very viscous. Surfaces coming in contact with these solutions should be materials such as stainless steel. Frequent jar test are necessary to assure proper dosages. Over-dosage (1.0-2.0 mg/l) can sometimes work against the treatment process.

3.2 Solvent Extraction is a separation process for washing a hazardous substance from either soil or water with a liquid solvent.

Extraction of soil may occur either in place or in a mixing device such as a screw conveyor. Liquid-liquid extraction is feasible as either a batch operation or as a continuous counter-current process.

Liquid-liquid extraction can be used to remove organic contaminants from aqueous mixtures. Current applications include extraction and recovery of phenols, oils, and organic acids. Solvent extraction does not produce a waste which can be directly discharged and further treatment is necessary. Multistage solvent extraction can reduce some contaminants to very low levels.

In situ treatment using solvent extraction techniques is not always recommended due to difficulties in recovering the contaminated solvent. Once the solvent is introduced to the water, and up to the extent of its solubility in water, it becomes a pollutant itself. On-site extraction is possible, however, by pumping the contaminated water into treatment tanks. Care must, therefore, be taken that the treatment system can remove or degrade the solvent. Desirable properties of liquid-liquid extraction solvents are: 1) relatively low aqueous solubility, 2) relatively non-polar, 3) non toxic, 4) high partition coefficient, 5)easy separation of solvent and water, 6) ease of handling, and 7) availability and cost.

Extraction of contaminated soils is also feasible. It is more effective for immediate spill situations where the hazardous material is entrained in voids in the soil rather than for clean-up of long term disposal sites when the hazardous material has adsorbed onto soil particles. Along this same line, the characteristics of the soil are critical. The presence of large rocks or boulders, the clay content, the water content, and the content of organic material are characteristics which determine the type of equipment chosen, the time required for treatment, and the type of soils that can be handled. High cohesive clay content is the most critical characteristic due to its resistance to mechanical breakdown. Most available soil handling equipment (sieves, crushers, etc.) is extremely limited in its application cohesive clays. Generally speaking, the clay content of soil should be less than 20-30% and dispersed before considering extraction.

The steps involved in extracting of contaminants from soil are:

1. Excavation
2. Mechanical breakdown of soil to manageable size
3. Treatment, which probably involves both physical stripping and extraction of hazardous material
4. Treatment and recycling of solvent.

Water or water with an additive (such as acids to improve removal of metals, or bases to improve removal and enhance safety of handling cyanide compounds, or oxidants to aid in removal of organics and reducing agents) is relatively effective for soil extractions as long as the contaminants have a relatively high water solubility and/or have a greater affinity for the water than the soil. Therefore, most water soluble organics and inorganics can be treated in this manner. Careful selection of a proper additive could increase the applicability of this method; however, it will require laboratory testing.

Other factors influencing the use of solvent extraction treatment techniques follow.

Limitations: In some cases only moderate removal of a contaminant will be accomplished, required in further treatment. Solvents must be recovered and treated to remove contaminants. No readily available commercial mobile system exists.

Requirements: Will require personnel familiar with extraction techniques. Site must be easily accessible to large equipment. Lab testing may be necessary before treatment in order to optimize the choice of solvent.

Availability: Mobile EPA system is available. Necessary equipment for construction of a similar unit is available off-the-shelf but will require feasibility and engineering design at considerable capital cost.

3.3 Solidification/Stabilization processes convert the hazardous substance to a form that is immobile and/or resistant to leaching from a landfill. Stabilization refers to a chemical reaction that fixes the hazardous substance prior to or during solidification. Solidification creates a stable mass either by physical encapsulation of the hazardous substance or by a combination of stabilization reaction and entrapment in a solid matrix. Some solidifying agents are used to make the hazardous substance easier to handle and transport, while some agents harden as a monolithic block suitable for disposal. Candidate processes and solidifying agents are discussed below.

3.3.1 Chelation/Sequestration

Chelation is more aptly described as a fixation process in that a hazardous material is bonded by the chelation agent in more than one position (making it unable to react chemically and thus less toxic). Chelation is applicable to aqueous solutions contaminated with heavy metal ions. There are two types of chelation agents: sequestrants which bind the metal ion but remain soluble within the water column, and precipitants which simply cause precipitation of the chelate-metal ion complex (and in this manner remove it from the water column) [see Section 3.9 for detailed discussion of precipitation]. Sequestrants have the disadvantage that, even though the metal ion has been detoxified to a certain degree, the complex remains in the water column, and can present a hazard in itself. Ethylene-diamine tetra-acetic acid (EDTA), for example, is a commonly used sequestrant and even has medicinal application as a treatment for metal poisoning. However, its aquatic toxicity threshold is in the range of 100 to 1000 ppm. Treatments requiring addition of EDTA in concentrations greater than 1000 ppm should, therefore, be carried out when human health considerations are the overriding concern.

Other chelating agents include 1,2-Diamino cyclo-hexane-tetraacetic acid (CDTA), Hydroxyethylethylenediamine-tetraacetic acid (HEDTA), Nitrilotriacetic acid (NTA), Sodium Tripolyphosphate (STPP), and Tetrasodium Pyrophosphate (TSPP). A chelating agent such as one of those given above should only be used *in situ* if the following criteria are met (otherwise measures to remove the metal-agent complex, e.g., by organic solvent extraction, will have to be used):

- Any agent or complex remaining in solution after treatment must be at a non-harmful level and should not produce adverse environmental effects, e.g., large pH changes.

- The removal of essential trace elements, such as calcium and magnesium, from the aquatic environment must be minimized.

- Misapplication of the treatment chemical should not cause a violation of water quality criteria.

- The reagent should be soluble in water to the extent required for application to the spill.

- It should be low cost and readily available.

- The metal chelate should be stable in solution against degradation for a reasonable time.

EDTA is ion-specific, depending on the pH. At 10 or above, calcium and magnesium are removed. At pH 8-10, iron and aluminum are selectively removed. EDTA is generally applied as the sodium salt in one of the following forms:

- EDTA disodium salt

- EDTA tetrasodium salt
- EDTA calcium disodium salt

The tetrasodium salt is least expensive but will produce an undesirable increase in the pH in case of misapplication. The disodium salt has a desirable solution pH and is more effective as a sequestrant than the calcium disodium salt. EDTA disodium salt is sold as a powder or crystal and is readily available. The cost is approximately $10.00/kg for bulk shipments.

3.3.2 Cements

Common cement. "Portland cement" is produced by firing a mixture of limestone and clay or other silicates at high temperatures. The resulting ash is then ground to a fine powder. The hardening of cement, brought about by the addition of water is a lengthy process which is affected by compounds such as sulfate, borates, salts of some metals, and a variety of organic compounds. Type "I" is "normal" cement constituting 90% of the cement manufactured in the U.S. and has been used for waste fixation. Most hazardous wastes slurried in water can be mixed directly with the cement and suspended solids will be incorporated into the rigid matrix of the hardened cement. Using cement to solidify wastes containing high concentrations of heavy metals is especially effective. However, salts of manganese, tin, zinc, copper, and lead increase setting time and lead to decreased strength. Large concentrations of sulfates have an especially detrimental effect on cement. A special low alumina cement (Type IV) has been developed for use in circumstances where high sulfate concentrations are encountered.

Certain actions must be taken before attempting solidification with cement, such as:

- Acidic waste streams should be neutralized.
- Generally, the higher the solids content, the less reagent that will be required. However, all insoluble materials passing through a No. 200 sieve (674 micron) are undesirable.
- Metals must be in the relatively insoluble hydroxide form prior to solidification to prevent leaching of soluble metals from the solid product.

- The presence of high concentrations of soluble or insoluble organics (1-5%) may adversely affect the curing process. Addition of clays such as bentonite may aid in adsorbing the organics.

- Wastes containing 1/2-5% NH_3- (ammonia) will generate ammonia gas upon addition of cement. Care must be exercised and respirators equipped with ammonia-gas canisters may be required.

- Cyanide-containing waste will require pretreatment before solidification, to achieve ultimate destruction of free cyanide.

The equipment necessary for this solidification process includes:

- disposable container or liner with internal mixing blades
- mixer
- cement hopper
- cement feed system
- dust collector
- pump skid
- control mechanism

Additional information on cement-based solidification is given below.

Limitations: Relatively large amounts of cement are required for most processes. Weight and balance of final product must be considered. Access to spill site will be required.

Availability: Cement and necessary equipment should be available within one day.

Costs: Costs will vary depending upon the type of waste to be treated. An approximate figure is $0.50/lb waste.

3.3.3 Gels

A gel is a colloid in which the disperse phase has combined with the continuous phase to produce a viscous jelly-like product. The submicroscopic particle groups can be crystalline or ionic. It consists of a colloidal solution of a liquid in a solid.

A reversible-gel is one that by heating or other treatment is converted into a liquid colloidal solution (SOL).

A thickener is a solid that is added to a liquid and dissolves in it causing a progressively higher viscosity liquid depending only on the amount of solid added.

The Calspan Corporation under EPA contract developed a formulation consisting of five individual materials which can be applied to many liquid spills. It was called a "Universal Gelling Agent (UGA)" but this is a misnomer. It is a mixture of five different materials.

1. To thicken aqueous solutions:
   Aqueous thickeners such as Gelgard M® (The Dow Chemical Co.) and/or Kelzan® (The Kelco Corp.)

2. To absorb many organic liquids and mixtures such as gasoline, aliphatics, aromatics, esters, ketones, and many low viscosity organics:
   Imbiber Beads (The EMCO Co. - Div. of ENSCO).
   The imbiber beads are absorbents for materials listed as well as adsorbent for all others. They do not dissolve.

3. To thicken polar organics:
   Hycar 1422® (B.F.Goodrich Co.) and/or Soloid® (Kelco Corp.) and/or Klucel® (Hercules Corp.)
   These materials are for glycol ethers, esters, ketones, highly polar organics - some chlorinated and aromatics. These materials are thickeners for materials listed and adsorbent for certain others. (They do dissolve in excess solvent.)

4. To thicken aqueous and alcoholic solutions:
   Carbopol 934® (BF Goodrich) and/or Klucel® (Hercules Co.)

These materials are thickeners for the materials listed and are adsorbent for certain others. (They do dissolve in excess solvent).

5. Fluidizing Agent (to coat other particles) to prevent clumping and promote free flowing.
   Cabosil® (Cabot Corporation)
   This is a colloidal silica that exhibits some gelling capability (colloidal) of its own in both aqueous and organic liquids.

While the components of UGA can be used separately, a determination of the type of hazardous material which has been spilled must be made. The UGA formulation can be applied to many spills without the need to determine the composition of the spilled material. The composition of UGA is as follows:

Gelgard M	5%	(thickener)
Imbiber Beads	30%	(absorbent)
Carbopol 934	25%	(thickener)
Hycar 1422	30%	(thickener)
Cabosil	10%	(gellant)

UGA is easily distributed either manually using shovels or by earth moving equipment (on land) or with devices such as pneumatic conveyor systems and sand blasting equipment such as MSA's Bontour rock duster. Removal of the spilled hazardous material can be accomplished using shovels or earth moving equipment for land spills and possibly mesh screen or booms for water spills.

UGA can be blended in either a powdered or granulated form, or chipped and compressed into sheets. The latter two forms have been found to have superior performance. UGA should be dispersed to form a homogeneous layer at a rate of approximately 1 lb/gal of spilled material. Gel time is approximately 10 minutes but will be affected by temperature and precipitation.

Additional information is given below:

Limitations: Wind, precipitation, and temperature variations will interfere with application and will affect gelling time. Gelled material should be considered hazardous and either disposed of properly or recycled. Care should be taken to prevent contact with skin and inhalation.

Availability and Costs: Components for UGA should be available and the necessary equipment should be available within 1/2-1 day. Cost vary from $0.50-3.00/lb (1975$) depending upon dispensing equipment used.

3.3.4 Lime

Solidification with lime products usually depends on the reaction of the lime with a fine-grained siliceous (pozzolonic) material to form a concrete-like material. The most commonly used pozzolonic materials include flyash, ground blast furnace slag, or cement kiln dust.

Advantages of lime-based techniques are:

- Lime and pozzolonic materials are readily available
- Equipment is readily available
- Extensive dewatering is not necessary as water is required in the setting reaction.

Disadvantages include:

- Weight and bulk to be transported and/or land filled
- Uncoated lime-fixed materials may require specially designed landfills to guarantee that the materials do not lose potential pollutants by leaching.
- Caustic materials like lime are corrosive to skin and lungs.

3.3.5 Organic Polymers

Organic polymer systems such as urea-formaldehyde and vinyl ester-styrene polymers have been developed in response to the requirement for solidification of radioactive waste before shipment. These vinyl-ester and polyester systems are currently being tested and are not yet available. The urea-formaldehyde process has been thoroughly tested. Urea-formaldehyde polymer systems are generally applied to a batch system where the polymer is added to either wet or dry wastes in the waste containers or special mixing containers. Once the two components are thoroughly mixed, a catalyst is added to form the polymer. The hazardous material is trapped within a sponge-like matrix. Liquids associated with the wastes will remain. Because of this, the technique is applicable to insoluble solid particles.

Major advantages of organic polymer systems, primarily urea-formaldehyde, are:

- Waste/fixative ratio approximately 30% greater than for cement or lime-based solidification technique.
- Treated waste material is usually dewatered but not dried. This technique provides drying for disposal.
- Organic resins weigh less than solidified cements, thus reducing transportation costs.
- Resin is non-flammable.

Inherent disadvantages of these systems include:

- Waste material is not chemically bonded to the resin matrix.
- Waste-polymer mixture must be maintained at a pH of 1.5 for solidification to occur rapidly.
- Uncombined water may be highly acidic and contain high concentrations of pollutants, requiring treatment or disposal.
- Some catalysts are highly corrosive and require special mixing equipment and lined containers.

3.3.6 Silicates

(Insufficient information available)

3.3.7 Thermoplastics

Thermoplastic materials like bitumen, asphalt, and other organics such as paraffin or polyethylene have been used to solidify radioactive wastes. Dried waste material is generally distributed in a heated plastic matrix. The matrix is then placed in a secondary container such as a steel drum and allowed to solidify before permanent disposal.

This solidification technique suffers from the fact that the fixative/waste ratio is large, generally 1:1 or 1:2 dry weight. The technique is also energy intensive, requiring elevated temperatures (130°C - 230°C).

The characteristics of the wastes will often prevent the use of this system. Obviously, organic solvents for the matrix cannot be present. Strong oxidizers will have a tendency to cause slow deterioration of the matrix. The major advantages of this process are:

- Contaminant migration rates generally less than encountered with cement-based methods.
- Resistant to aqueous solutions.
- Good adherence to embedded material.

The main disadvantages are:

- Specialized equipment and trained personnel are required.
- Wastes containing volatile components can produce potentially toxic gases when heated.
- Wastes containing water must be dried before they can be mixed with the thermoplastic.

3.4 Ion Exchange is the reversible interchange of ions between an insoluble, solid salt (ion exchange resin) and an electrolyte solution in contact with the solid, substituting less hazardous ions for the hazardous ions in solution. In this process ions, held by electrostatic forces to functional groups on the surface of a solid, are exchanged for ions of a different species in solution. This takes place on a resin which is usually made of a synthetic material. Various kinds of resins are available, including weakly and strongly basic anion exchangers and weakly and strongly acidic cation exchangers. The ions are exchanged until the resin is exhausted. Most ion exchange resins are capable of regeneration with solutions of the H_2SO_4, NaCl, NaOH, or NH_3 depending upon resin type.

Capacities of resins vary greatly with the manufacturer of the resin. The amount of resin needed must be determined by chemical tests using the wastewater to be treated. A resin manufacturer should also be contacted to ensure the correct choice of resins. In order to facilitate the proper selection, the following items of information should be available: (1) name of hazardous material to be removed, (2) concentraton (approximate) of hazardous substance, (3) amount of wastewater to be treated, and (4) chemical analysis of ions.

Ion exchange is considered an external treatment in which the spilled material is pumped through the resin. The resin can either be in loose form or contained in packed columns. The latter method provides much greater removal efficiency. It can be considered a polishing method; however, the effluent may be a concentrated salt solution, and as such, will require a controlled discharge to a receiving water or a municipal sewer, or removal to a suitable disposal site. This may require special permits.

When using ion exchange resins, several precautions should be taken. First, unless absolutely necessary, the resins will not be regenerated in the field. Second, in order to avoid breakthrough (incomplete removal of contaminant due to exhausted resin), continuous monitoring of the effluent should be conducted. Third, suspended solids will seriously affect the efficiency of the ion exchange resin. For this reason prefiltration is a necessary step. Lastly, it must be remembered that synthetic resins consist of organic components. Strong oxidizing agents such as nitric acid attack the resins under certain conditions, resulting in slightly degraded resin, or possibly, an explosive reaction.

Availability: Ion exchange resins are readily available off-the-shelf from many manufacturers. The principal ion-exchange producers in the United States are:

Company	Location	Trademark
Diamond Alkali Co.	Redwood City, CA	Duolite
The Dow Chemical Co.	Midland, MI	Dowex
Ionac Chemical Corp.	Birmingham, NJ	Ionac
Rohm & Haas Co.	Philadelphia, PA	Amberlite

Costs: Resin generally sells for between $30 and $180 per cubic foot.

3.4.1 Cationic Resins

Cationic resins are capable of removing cations (positive ions) from solution. These resins consist of a negatively charged matrix and exchangeable cations (for example, H^+) are substituted by the specific cation in solution. Cation exchange resins can then be used to remove positive ions such as heavy metals. Commonly used cationic exchange resins are sulfonate groups attached to an insoluble polymer network.

3.4.2 Anionic Resins

Anionic resins are the exact opposite of the cationic resins. That is, they serve to remove negative ions (anions) from solution. Thus they are useful in removing ions such as cyanide from waste water.

3.5 Hydrolysis is a chemical process which involves a water-induced bond cleavage to produce a double decomposition. However, organic hydrolysis can also include reactions in which water is not a reactant. Acid, alkalis, and enzymes, to a certain extent, are used as catalysts in many industrial processes. Acid and alkaline hydrolysis are discussed in this section.

Hydroloysis may be applied to a wide range of waste types, primarily for destruction of nitriles, amides, esters, and some chlorinated hydrocarbons. Familiarity with the specific reaction chemistry is necessary before this technique should be used to treat wastes, due to the fact that the hydrolysis reaction products are often as toxic, or even more toxic, than the original waste component. Because of this, in situ hydrolysis is not a recommended course of action. For example, hydrolysis of the pesticide parathion yields as one of the reaction products p-nitrophenol which is also quite toxic.

Hydrolysis is a common commercial process which can be conducted with relatively simple equipment (e.g., batch-wise in open tanks) or in more elaborate equipment (e.g., counter-current towers). Capital costs will vary considerably depending upon the equipment and operating temperature and pressure. Raw material costs are usually small.

3.5.1 Acid Hydrolysis

The agents for acid hydrolysis are most commonly hydrochloric and sulfuric acids, but others such as formic and oxalic acids are also potential reagents. Muriatic acid (30% hydrochloric acid solution) is readily available at hardware stores. Sulfuric acid (20%) is available in the form of drain cleaner products and can be used. It must be remembered, however, that these materials are extremely corrosive and must be handled with care.

Acid hydrolysis usually proceeds more rapidly in solution. Thus, stirring in an open container with excess acid is feasible though potentially dangerous. Another method is to mix the waste with sand or other adsorbent in a pit or trench and then add the acid. Disposal of wastes by this method cannot be performed in an area where groundwater contamination is possible. Treated waste streams will generally require pH adjustment before they can be discharged.

One final word of caution. *Do not treat cyanides or phosphides with strong acids as hydrogen cyanide gas and phosphine gas, both highly toxic, will be given off as reaction products.*

3.5.2 Alkaline Hydrolysis

Alkaline hydrolysis mostly utilizes sodium hydroxide, but alkali carbonates (limestone), alkaline hypochlorite, calcium compounds (lime, slaked lime), and magnesium and aluminum compounds are also used.

As with acid hydrolysis, alkaline hydrolysis can be performed in batch processes in open tanks with stirring, although this may be dangerous. Treatment in a trench filled with adsorbent material is recommended for treatment of small quanties of wastes, expecially pesticide wastes. This should be done only in areas where groundwater contamination will not occur.

If a large volume of waste is to be discharged after treatment, it will probably be necessary to adjust the pH.

3.6 *Neutralization* refers to the interaction of an acid with a base. The reaction products are water, a salt, and sometimes carbon dioxide gas. Neutralization is applicable to spills of acidic or alkaline hazardous materials (or substances which when spilled into water form an acid or a base) and can be applied *in situ* under the proper circumstances. In emergency field situations, the factors limiting the use of neutralization often are the volume of the spill, the violence of the neutralization reactions, and the production of potentially toxic gases. The final pH of the neutralized hazardous substance would generally be environmentally acceptable if in the range of 6.0 to 9.0.

Neutralization has been used in a number of spill response efforts, each involving different hazardous materials and circumstances. When treating a hazardous substance spill *in situ*, regardless of the circumstances or the substance involved, the following factors should be considered:

- Certain acids and bases used to neutralize a spill can cause toxic pH changes in the environment, especially if applied to spills in water. The change in pH upon addition of the neutralizer must be carefully monitored. When possible, treat with weak acids and weak bases as there is less chance of large pH changes caused by over application of the neutralizer.

- For water spills, it is often necessary to use a precipitating agent as a post treatment in order to remove metal ions which could be evolved during the neutralization process.

- Often neutralization reactions are violent (frothing and sputtering, with evaluation of heat and gases). Because of this, personal protection from skin contact and inhalation of fumes is absolutely necessary. Sputtering can be controlled by minimizing the reaction temperature, or diluting the reactants.
- Under-treatment is preferable to over-treatment. The desired pH will rarely be achieved. A final pH range of 6.0 to 9.0 in treated wastes is acceptable.
- If a spill of a very weak acid or base does not cause the pH to deviate outside the 6-9 range when spilled into water, neutralization is not recommended.

3.6.1 Neutralization with Acid

After recovery of as much material as possible for recycle or reuse, neutralization of a spill of a strong base is done most economically with a strong acid. For land spills where the remainder, of the spilled strong base, is contained (i.e., lined trench, concrete), neutralization with strong acids (i.e., hydrochloric, sulfuric) can be accomplished. In a non-porous soil, mechanical mixing to depth of penetration can be done and then the neutralized soil may be excavated for disposal. Only qualified personnel should handle the neutralization process and small scale field tests should first be performed to determine if any negative (i.e., heat generation) reactions take place.

Aqueous spills of bases compounds that react with water to form bases should be treated with weaker acids to prevent harmful pH changes caused by an overdose of the acid neutralizing agent. Examples of these are acetic acid, sodium dihydrogen phosphate, and even gaseous CO_2. Sodium dihydrogen phosphate is applicable in all situations because it is a buffer salt which tends to keep the pH within a certain range. Overdosing, at most, would cause the pH to decrease to approximately 4.0. The user should be aware that the neutralized products of acetic acid and sodium dihydrogen phosphate, namely, acetates and phosphates, may be unacceptable for discharge. CO_2 also acts as a buffer and has been used to neutralize ammonia spills in water, but it is difficult to dissolve and disperse properly.

Additional information is given below:

Availability and Costs: All of these materials should be readily obtainable and ready for use wthin one day.

Costs: (1975 $)	Sulfuric acid	$0.025/lb	(dil. aq. sol.)
	Acetic acid	$0.15/lb	(dil. aq. sol.)
	Sodium dihydrogen phosphate	$0.17/lb	(dry powder)

3.6.2 Neutralization with Base

The use of strong bases as neutralizing agents should be limited to spills of strong acids on land where effective containment is possible and control of the reaction is somewhat achievable. Treatment of water spills should be limited to the use of weak bases. For land spills, aqueous sodium bicarbonate, sodium carbonate, or sodium hydroxide solution is often added to spilled material contained in a lined trench. This technique has been successfully used to neutralize several chlorine spills. Acid spills can also be treated with lime, sodium carbonate, soda ash, and magnesium hydroxide. A technique which has been successfully employed to prevent frothing and sputtering when neutralizing an acid spill with limestone, is to mix flyash with the acid before adding the limestone.

Spills of acids in water or substances which react with water to form acids should be treated with weak bases. Examples of applicable neutralizing agents are:

- sodium bicarbonate
- sodium carbonate
- calcium carbonate

Lime or calcium hydroxide are also used, but addition of these materials in excess will cause large changes in the pH. Although reaction rates will generally be slower for calcium carbonate than for the sodium-based agents, calcium carbonate, on the other hand, has several distinct advantages for use in neutralizing water spills:

1. Reaction with acid produces CO_2 which levitates calcium carbonate particles to provide mixing and a more complete reaction.

2. Carbonate and calcium are both present naturally in surface water. Calcium carbonate, therefore, does not add any toxic elements to the environment.

3. The maximum pH due to overdosing is 9.4.

4. Widespread use makes calcium carbonate readily available.

Sodium bicarbonate, a buffer salt, can also be used without threat of large pH overshoot in case of overdose. The maximum pH resulting from an overdose is 8.3. Sodium carbonate solutions in water, on the other hand, are almost as basic as sodium hydroxide. This overdosing can push the pH to 11.6.

Care must be exercised at all times when handling any of these materials. Inhalation of fumes and contact with skin must be avoided.

3.7 Oxidation-Reduction reactions are chemical reactions in which the oxidation state of at least one reactant is raised while that of another is lowered. Detoxification of hazardous substances may come as a direct result of the change in valence state of ionic species, or it may result from the consequent destruction of chemical bonds.

Both oxidation and reduction processes are in widespread use in industry. Oxidation is commonly used for treatment of aqueous wastes containing cyanides, phenols, other organics, and sulfur compounds. Reduction is generally employed to increase removal efficiency of certain inorganic ions (such as heavy metals) in dilute waste streams. For example, reduction reactions are currently used to remove lead from oil and mercury from effluents, and for the reduction of chromium in effluents to enhance its precipitation.

Often catalysts are used to speed up the reaction rate. Activated carbon is an effective catalyst for nitrile and cyanide oxidation. Catalysts such as zinc, copper, silver, nickel, palladium, etc., can be used.

Oxidation reactions may be slow, often producing intermediate reaction products which may be toxic and probably stay in the environment unless over-treatment with the oxidizing agent is performed. This, however, will almost certainly produce severe toxic conditions. In addition, oxidation reactions cannot be limited to reactions with the spilled material. Oxidation of organic material in the environment including living organisms will always accompany oxidation of a spilled material. For these reasons, in situ oxidation is not recommended and should be considered only as a last choice.

Additionally, oxidants should only be used on land and in surface waters when the spilled material can be contained for a sufficient time to permit accurate control and monitoring of the treatment. Oxidation of pesticides such as ethion or malathion containing phosphorodiothioate and phosphorodithioate function groups should not be attempted because of potentially toxic products.

The same is basically true for reduction reactions. Some reactions, such as calcium sulfite with chlorine produce oxidizing agents as intermediary products, in this case hypochlorite ion. It is difficult to avoid adding excess reducing agents which are necessary for a complete reaction. Reductants applied to spills in water can increase both the chemical oxygen demand (COD) and the biological oxygen demand (BOD) to intolerable levels. Candidate oxidation and reduction agents are discussed below.

3.7.1 Oxidation

Chlorine as an oxidant, is generally applied to a spill as sodium hypochlorite or, less frequently, as calcium hypochlorite. Sodium hypochlorite is available in an aqueous solution (household bleach). Sodium hypochlorite has been shown to be effective in the treatment of cyanides and nitriles, aliphatic amines, and phenolic compounds. In the treatment of phenols, an elevated pH (>10) is usually necessary in order to ensure a complete reaction and limit the formation of incomplete reaction products (e.g., chlorinated phenols). Free chlorine, either as a gas (land spill applications) or as chlorine ions (water spills), is a product of the oxidation reaction. Therefore, extreme care must be utilized. Chlorine gas generated by the application of sodium hypochlorite to a land spill can be allowed to dissipate in the atmosphere. Chloride produced in an aqueous solution, however, must be removed by further treatment such as activated carbon adsorption. Chlorine is readily available and costs approximately \$0.063/lb in ton quantities (1976 \$). Calcium and sodium hypochlorite are also readily available and costs range between \$0.47 and 0.58/lb (1976\$).

Note that an alkaline pH is required in aqueous solution containing cyanides before treatment with chlorine. Acid pH will facilitate the formation of hydrogen cyanide and/or cyanogen chloride, both of which are highly toxic.

Hydrogen peroxide has been shown to react with sulfides, mercaptans, amines, phenols, and cyanides. Metal salts, particularly iron salts such as ferrous sulfate, are necessary as catalysts in order to complete the oxidation reaction. Other metals such as aluminum, copper, and chromium will also work. Hydrogen peroxide is readily available in aqueous solutions, typically 35, 50, and 70%. Typical cost for a 35% solution of hydrogen peroxide is \$0.155/lb (1976 \$).

Ozone is one of the most powerful oxidants known to man and has been shown to oxidize phenolics, cyanides, PCBs, water insoluble organics, biodegradable organics, and certain soluble organic chemicals, such as glycols and ethers. Products of ozone oxidation reactions are dependent upon the specific treated compounds but can include carbon dioxide, ketones, aldehydes, organic acids, peroxides, expoxides, nitro and nitroso compounds, sulfones, sulfoxides, and other oxygenated species. Care must be exercised, therefore, to ensure that no hazardous or toxic reaction products are present before discharging treated wastes.

Ozone can be employed in either a batch or continuous system. Commercial systems employ techniques such as diffusion, positive pressure injection, mechanical mixing, spray chambers, etc., to ensure contact between the ozone and waste material. Because ozone is an unstable gas, it is generated on-site primarily by electric discharge. A relatively new development is treatment of wastes with a combination of ozone and ultraviolet radiation. This method has proved effective for the destruction of many toxic and refractory organics, organometallic complexes, and reduced inorganic substances.

Due to high capital costs associated with the construction of an ozonolysis unit, ozone oxidation is generally a final, polishing step. The estimated cost for construction of a mobile ozonolysis unit with a 60,000 gallon/day capacity, is $285,000 (1981 $). The relatively sophisticated technology and high cost have limited the use of ozone oxidation to fixed facilities and, at present, there are no mobile units to be used for emergency spill response.

It should be noted that ozone is toxic and may be lethal with prolonged exposure. Precautions must be taken to prevent personnel from coming into contact with ozone.

Potassium permanganate has been used for destruction of organic residues in wastewater such as aldehydes, mercaptans, phenols, and unsaturated acids. It is a relatively powerful oxidizing agent. The oxidation reaction produces insoluble manganese dioxide which must be filtered and removed before discharging treated waste. Potassium permanganate is readily available and costs approximately $0.52/lb in 350 lb barrels (1976 $).

3.7.2 Reduction

Chemical reduction is used primarily to control hexavalent chromium in the plating and tanning industries and to remove mercury from caustic/chlorine electrolysis cell effluents. Reduction can also be used to remove other heavy metals such as antimony and lead from waste streams. For chromium removal the following reductions are generally used:

- sulfur dioxide
- sodium bisulfite, meta bisulfite, hydrosulfite
- ferrous sulfate
- calcium sulfite

Calcium sulfite and sodium bisulfite have also been shown to be effective amelioration techniques for chlorine spills in which hypochlorite ion is a major initial product (i.e., in water). For wastes containing mercury, lead, antimony, etc., sodium borohydride is generally used.

Reduction reactions generally result in the introduction of new ions or a precipitate into the effluent. In both cases, additional treatment such as precipitation, sedimentation, or filtration will be necessary before the effluent can be discharged. Only when the original waste constituents were present in very small quantities can the resulting reaction products be ignored.

3.8 Polymerization here refers to the in situ catalysis of a free-radical addition reaction of a released monomer. In-place polymerization serves to make the hazardous substance less mobile and less hazardous, while also facilitating subsequent removal. This process differs from the stabilization/solidification process involving organic sedimentation (Section 3.3.5) in that this treatment entails application of a catalyst to polymerize the spill of a released monomer. Stabilization/solidification, on the other hand, refer to the addition of a monomer/catalyst pair to a spilled hazardous material.

Studies have been conducted to determine the feasibility of using subsurface injection techniques to polymerize a spill. In certain studies, persulfate was used to polymerize styrene. Results indicate that, in general, it is difficult to obtain rapid polymerization under ambient conditions typical of real spill situations. Futhermore, polymerization is limited to a few hazardous materials, requires an elaborate subsurface injection system and has been determined to be a dangerous technique to implement under field conditions. Until the technique is further refined and becomes more feasible, in situ polymerization is not recommended.

3.9 Precipitation is a physicochemical process whereby a substance in solution is transformed into a solid phase and driven out of solution. Precipitation entails altering the chemical equilibrium affecting the solubility of the hazardous component by either adjusting the pH of the solution (often involving a redox reaction and sometimes floc formation), or by adding a substance that will react with the dissolved substance to form a less soluble product.

Precipitation reactions can also follow as a result of a temperature change (see Section 2.2). Current application of precipitation with respect to hazardous waste treatment include the removal of heavy metals from wastewater by lime treatment, treatment of dye manufacturing wastes, and removal of organic colloids from pulp and paper mill wastewater effluents. Precipitation may be applied to almost any liquid waste stream containing hazardous solids which can be settled out of solution.

There are many factors which affect the efficiency of precipitation (pH, nature and concentration of hazardous substances in water, precipitant dosage, temperature, water turbulence, etc.). In practice, the optimum precipitant and dosage for a particular application are determined by a "trial and error" approach using jar tests.

In situ precipitation has certain inherent disadvantages. Foremost among these is that lacking an effective means for removing the precipitate subjects the water course to a build-up of particulate matter which, in the long term, may prove to be as toxic to the environment as the original spilled material. If the precipitate did not settle out, colloidal precipitate would threaten gilled species and reduce recreational and aesthetic benefits.

These difficulties are overcome, however, if the contaminated water is pumped into a treatment system where precipitation followed by sedimentation and collection of the precipitate could be performed before discharging the treated water. The equipment necessary for this treatment system is fairly simple and readily available:

- Pump
- Precipitation Tank
- Solids Separator
- Precipitate Storage Vessel

Candidate precipitating agents are discussed briefly below.

Hydroxides for most heavy metals can be precipitated by the addition of sodium hydroxide (caustic soda), calcium hydroxide, and lime. Many metal/hydroxides are insoluble only at elevated pH (8.0-11.0); therefore, pretreatment to raise the pH will usually be necessary. In situ treatment of water spills is not recommended because of this requirement. Additionally, unless the precipitate is removed from the watercourse, it could begin to redissolve as the pH returns to normal. In situ treatment of land spills is possible, e.g., by spreading lime, over the spill after the pH has been raised to ensure minimum solubility. The resulting sludge must be disposed of properly, yet precipitated metal hydroxide sludges are difficult to dewater.

Sulfide, in the form of sodium sulfide, is an effective precipitating agent for application to spills of heavy metal compounds. Sulfide treatment is frequently used as a polishing step following treatment with a hydroxide precipitating agent. Hydroxide treatment is often incomplete due to solubility of some metal hydroxides or incomplete sedimentation of fine particles. Metal sulfides are several orders of magnitude more insoluble than the corresponding hydroxides. Coagulation or fine particle filtration may be required for metal sulfide removal.

Treatment of certain anionic "ate" ions, such as chromate, manganate, vanadate, etc. with sodium sulfide is not recommended due to the potential formation of toxic hydrogen sulfide. Caution must be exercised when applying sodium sulfide as it is itself toxic and highly alkaline because of hydrolysis to sodium hydroxide (0.1N solution has pH 13.0).

Tests have also been performed on heavy metal spills on land which indicate that sodium sulfide treatment reduces heavy metal runoff by partially immobilizing the spill. A recommended treatment material is a solution of 85 g/l sodium sulfide stabilized with 18 g of sodium hydroxide. This solution can be stored indefinitely at room temperature.

Other potential precipitating agents have been discussed in previous sections (see Section 3.1 and 3.3.1). Other candidate materials include the following:

- Dibasic sodium phosphate
- Sodium chloride (no treatment in marine waters)
- Ferrous sulfate
- Ferric chloride
- Ferrous sulfide

Jar test using the above agents should be performed to determine their effectiveness. As with the other precipitating agents, they are generally useful on spills of heavy metal compounds.

4.0 BIOLOGICAL TREATMENT is a biochemical transformation process during which biodegradable hazardous substances are brought into contact with either mixtures of microorganisms, enzymes which decompose the hazardous substance, or with plants which accumulate the hazardous substance. Water and a carbon source are indispensible requisites for degradation by microorganisms. Additionally, biological treatment processes must address: (1) the need for well-developed treatability studies, (2) provision for time to acclimate and develop a suitable biomass, and (3) the process for sludge (excess biomass) disposal. Biological treatment is often combined with physical or chemical treatment.

Factors which will limit the use of biological treatment include a variety of chemical, physical, and environmental considerations. In general, hazardous materials with complex chemical structures such as aromatics and fully halogenated aliphatics, and "chicken wire structures" such as lignons are resistant to biodegradation. Physical phenomena such as high organic concentration, high molecular weight, and low solubility also hinder biodegradation. The biological treatment methods discussed in this section include conventional secondary wastewater treatment processes, such as suspended and fixed media growth, anaerobic and aerobic digestion, composting, enzyme treatment, land treatment, and _in situ_ assimilation. With the exception of _in situ_ and land treatment, the other methods could utilize a municipal sewage treatment plant, or Publicly Owned Treatment Works (POTW). This is a viable option for disposal of spill residues, assuming that the material is biodegradable. However, care must be taken to avoid plant upsets and possible shutdown due to spikes of toxic materials or surges of biodegradable material. Permission must be obtained to use the POTW. Contracting the services of a private waste disposal firm which operates a biological treatment facility is another alternative which also includes land treatment.

4.1 _Secondary wastewater treatment_ processes place a substance in an aqueous medium in contact with a mixture of microorganisms so that the biodegradable compounds present are decomposed under aerobic conditions. These microorganisms may be grown either in suspension or on a solid surface which is in intermittent contact with the liquid. These processes employ either suspended growth methods (such as activated sludge and aeration) or fixed media growth. These methods are the predominant biological treatment processes for industrial wastes and municipal wastewater treatment facilities.

Suspended Growth: Activated sludge processes utilize a microbial population which has been acclimated to a particular waste stream to increase the rate of degradation. The aeration process is necessary in order to maintain sufficient dissolved oxygen for the microbes and at the same time provide a mixing mechanism to keep the microbes in constant contact with the wastewater. The activated sludge process may be applied to wastewaters with less than 1% suspended solids and heavy metal content of less than 10 mg/l. It is very effective for degradation of organic wastes.

On-site biological treatment using the activated sludge process is feasible. Union Carbide Corporation, developer of an activated sludge process using oxygen in place of air (UNOX), has various sized mobile pilot plants which utilize this process. These units have a maximum hydraulic capacity of approximately 6,250 gallons per day. Information on these units follow:

Limitations: A long start-up and stabilization process is required (inherent in biological processes). Lengthy bench scale testing is also required to determine treatability and optimum operation conditions. This process is unsuitable for wastewaters containing volatile hydrocarbons.

Requirements: Trained operating personnel.

Cost (1981 $): Purchase price is approximately $250,000; however, the system may be leased. A list of approximate leasing costs follows:

- $5,000.00 - initial checkout of system
- $420/day - on-site including engineering consultation on program plan and execution
- $70/day - equipment rental
- Transportation - Varies depending upon several factors, e.g., distance, weight

Another suspended growth process is contact stabilization, a variation of the activated sludge process. Using this process, wastewater is placed in a shallow holding pond with the intent to utilize indigenous microorganisms to degrade organic waste. This process has been shown to be applicable only to aqueous waste streams with dilute organic and inorganic constituents due to the prolonged retention times required to allow biodegradation of hazardous organics. It is generally used to polish wastewaters which have already been treated.

Fixed media growth is a process where the microbial populations are grown on a supported, solid surface such as rock, plastic, rotating plastic disks, etc. Wastewaters are generally sprayed or trickled over the cultures, forming a thin layer of wastewater in contact with the microbes, where atmospheric oxygen penetrates the liquid layer and is available to the underlying biofilm. Trickling filters, rotating biodisks, and biological towers are commonly employed systems.

These processes are useful primarily as a pretreatment for other forms of biological treatment because of the low removal efficiency of most organics.

4.2 Digestion is a biological treatment process that is less reliant on an aqueous medium than conventional, secondary treatment, and that is typically used to hydrolyze insoluble substances. Organic substances may be digested by microorganisms in either an anoxic (metabolic reduction) or an aerobic (metabolic oxidation) environment. Composting, or aerobic digestion in windrows of the soil surface, produces no sludge unless remaining toxic contaminants are excessive.

Anaerobic digestion utilizes microorganisms to degrade organic wastes in the absence of oxygen. Complete anaerobic digestion results in the production of methane. Reduction, as opposed to oxidation, is the primary driving reaction in anaerobic digestion. Thus, anaerobic digestion will, in general, degrade chlorinated pesticides more rapidly through reductive dechlorination.

Anaerobic digestion, as a pretreatment step before aerobic processes, reduces certain major expenses of aerobic treatment such as oxygenating wastewaters and sludge handling and disposal. Generally, pretreatment of hazardous waste by anaerobic digestion will yield a sludge which should be more amenable to land treatment.

Aerobic digestion is one of the most widely used methods of composting which degrades a waste at elevated temperatures. In this process, the waste is placed in a controlled environment where the energy produced by microbial action is contained, resulting in an increase in the temperature. An abundant supply of oxygen coupled with high temperature and moisture results in accelerated decomposition. It is applicable to organic sludges and aqueous waste.

Composting is generally accomplished utilizing one of three methods: windrows, piles, and mechanical systems. Bulking agents, such as rice hulls, wood chips, or shredded straw, are used to reduce moisture content in the waste to 40-60%. One of the major advantages of composting is that it is the only biological treatment that is relatively insensitive to solvent organics and heavy metals. A disadvantage of this system is that leachate must be collected and treated. Costs associated with land farming are generally $0.02-0.09 per gallon or $5-24 per ton (1981 $).

4.3 Enzyme treatment is classed as biological treatment because enzymes must be produced by living cells. Enzymes are simple or combined proteins that act as catalysts for specific decomposition reactions involving only certain hazardous chemicals. Enzymes cannot be adapted or acclimated to varying substrates and are highly sensitive to pH and temperature conditions. For these reasons, enzyme treatment has little application for treatment of complex mixtures. They may also be inhibited by the presence of soluble inorganics and heavy metals.

4.4 Groundwater seeding refers to biological renovation of contaminated groundwater, either by injecting microorganisms below the water table or by pumping up the groundwater, inoculating it with microoroganisms, and reinjecting the water below ground. (Some phases of groundwater seeding are covered by patents.) Bioreclamation of groundwater is most often combined with aeration to enhance the microbial decomposition of the hazardous constituents. This process is really a suspended growth process similar to activated sludge; however, rather than heating contaminated water in above ground storage ponds, the microbial decomposition of wastes takes place below ground. A description of the steps involved in this process is given in Section 4.6.

4.5 Land application or land farming, involves the use of plants, the soil surface, and the soil matrix to remove hazardous constituents from aqueous solutions. Although the ultimate objective may be biodegradation, a variety of physical and chemical treatment processes come into effect in the renovation of land-applied wastewaters. Meteorological conditions are critical for proper operation of land application systems. Many crops are dormant in winter, reducing crop uptake of nutrients. Also, the crops must be harvested regularly.

To implement land applications, the following information must be available: 1) rate of decomposition, 2) critical concentrations in soil affecting vegetation, and 3) migration potential. Land treatment facilities are designed so that the following objectives are accomplished without damaging the environment:

- Breakdown of a portion of the waste through biological and chemical reactions.
- Adsorption and fixation of other waste constituents.
- Controlled migration for certain inorganic fractions.

Off-site land application techniques may be divided into three classes: slow-rate, which entails the irrigation and harvest of crops which may also restabilize the site; rapid infiltration, which commonly recharges the groundwater; and overland flow, which produces an effluent.

Slow rate systems involve the application of wastewaters to vegetated soils where they slowly travel through the soil matrix. During this percolation the waters are treated by a number of processes including filtration, adsorption, ion exchange, precipitation, microbial action, and plant uptake (unless an underdrainage system is used).

Overland flow processed wastewater is applied over the upper reaches of sloped terraces and is treated as it flows in a thin sheet down vegetated slopes to collection ditches or trenches. Perennial grasses with long growing seasons, high moisture tolerance, and extensive root systems, e.g., bermuda, are best suited to overland flow. Biological oxidation, sedimentation, and grass filtration are the primary removal mechanism for organics and suspended solids.

Wastewater is generally applied to soil with low permeability using either a sprinkler system or by flooding a diked field with several inches of the wastewater using gravity flow. Underdrainage systems can be used to recover effluent, to control groundwater, or to prevent leachate migration to other surrounding areas. Wastewater which has a high metal content should be pretreated to avoid soil and plant contamination.

Rapid infiltration techniques involves application of wastewater to highly permeable and thick soil deposits such as sand or sandy loam. Wastewater is applied primariy by flooding a diked field; however, sprinklers are used on occasion. The wastes are treated as they travel through the soil by filtration, adsorption, ion exchange, precipitation, and microbial action. Most metals are retained on the soil and many toxic organics are degraded and adsorbed. It is recommended, however, that the waste be pretreated to remove heavy metals, since the water will eventually reach the groundwater.

4.6 In situ assimilation is an on-site biological treatment; either on land or in surface-water bodies. In water, assimilation may be preceded by mechanical or chemical dispersion. In situ assimilation may be an active technique, as when the impacted medium is inoculated with microorganisms, or passive, as when indigenous biota are relied upon to accomplish the degradation. It is applicable to spill scenarios where the long-term threat is minimal. Also, in situ treatment is relatively untried.

Determination of the applicability of in situ biological treatment to a given hazardous material spill depends upon several key factors which include:

1. Spilled material is an organic compound containing no heavy metal.
2. Material is neither gaseous or critically toxic (which would necessitate immediate removal).
3. Material is biodegradable.

If these factors are satisfied, in situ biological treatment can be considered.

Factors which will limit in situ degradation include a variety of chemical and physical properties which were discussed at the beginning of this section, and several environmental factors. High concentrations of a spilled hazardous material and deficient soil conditions such as low moisture content will adversely affect biodegradation, as will extremes of pH, temperature, and nutrient levels. Optimum environmental conditions, in general, are: 1) pH of range 7.0-8.5, 2) temperature range 15-35°C, 3) nutrient levels of nitrogen and phosphorus, 4) 40% by weight moisture in soil. Adequate mixing (aeration or cultivation) is also needed.

It is entirely possible that the spill of a hazardous material will destroy the natural microbial population. In order for in situ biological treatment to remain a viable option, the factors that caused the sterilization must be corrected, (e.g., neutralize with acid or base, or disperse and dilute to a certain extent). Even though the native microbes have been destroyed, biological treatment is still possible by deploying specialized mutant strains of microbes. However, the value of mutant organisms (super bugs) is still being debated. These strains are commercially produced and are available in a fresh liquid state, a powdered state, or freshly reconstituted. The potentially harmful secondary effect caused by the addition of a foreign microorganism to the environment will generally be minor because once the hazardous material has been digested, the foreign added microorganisms will probably die and become a source of nourishment for the naturally occurring microorganisms. One problem associated with the addition of microorganisms to contaminated water is a resulting significant increase in the consumption of dissolved oxygen. Low dissolved oxygen levels could prove to be detrimental to existing aquatic organisms. This problem can be minimized, however, by providing adequate aeration or using small amounts of added bacteria so that excessive oxygen consumption does not occur. Several treatment schemes are possible, depending upon the spill scenario (land or water, land spill with contaminated groundwater, etc.). Brief outlines for land spill and water spill treatment procedures are given below:

Water Spill

- Impound contaminated water
- Remove any bulk chemical
- Environmentally conditions water (pH, nutrients, temperature)
- Seed with microorganisms
- Aerate
- Polish water as necessary (e.g., activated carbon adsorption)
- Recharge with more microorganisms or discharge as appropriate.

Land Spill

- Contain runoff
- Collect and remove bulk chemical
- Condition soil (pH, nutrients, water, cultivation)
- Seed with microorganisms
- Continue cultivation

Contaminated Groundwater

- Impound water
- Recover and remove bulk chemical
- Prepare recovery wells
- Condition impoundment water (pH, nutrients)
- Seed with microorganisms
- Recirculate treated leachate to ground
- Polish treated leachate as necessary (e.g., activated carbon adsorption)
- Discharge to receiving waters

Effective and safe implementation of *in situ* biological treatment requires a thorough knowledge of site geology and topography, hydrology, and soil types, as well as biology.

5.0 ULTIMATE DISPOSAL/DESTRUCTION processes within this category are not considered immediate response countermeasures as were discussed in previous sections (exception, Section 4.0 Biological Treatment). The processes discussed in this section are methods by which hazardous chemicals, contaminated solids, and aqueous wastes are ultimately disposed of or destroyed, once the initial containment/treatment has been completed. Some of these processes can be conducted at the spill site, but most will require that the contaminated materials be transported to a specific off-site location.

5.1 Open burning is in situ, open-air burning without controlled operation conditions. Extinguishment is, in general, not used when a fire is already in progress and the hazards of extinguishment are greater than the hazards presented by the fire. Open burning is considered one of the most dangerous treatment methods and should be attempted only after careful review of all alternative countermeasures. Its use for spills in water is applicable only to floating volatile substances, and its use for both land and water spills is limited to situations where the volume of spilled material is small and where material remains confined (in an isolated area).

Extensive air monitoring is required during open burning as many hazardous materials emit highly toxic vapors when heated to decomposition. Consequently, burning may intensify hazardous conditions and force the evacuation of areas surrounding the spill. Environmental factors, such as precipitation, have to be considered before a decision to burn can be made. In addition, open burning requires approval from air pollution control authorities.

Several methods for igniting open spills are available; however, none of them should be considered safe.

Incendiary Bombs - Thermite ($0.55/lb) burns at 3300°F for several minutes.

Flame Throwers - Commercial device will throw a flame approximately 20 ft for a duration of 5-8 sec. Contain 25 lb of fuel ($260).

Air Curtains - Commercial device creates incinerator-like conditions. Hazardous material is drained into a trench at a certain rate, an air curtain is placed over the trench and the vapors are ignited. Supercharging the air curtain causes vapors to be oxidized completely. (21 ft section w/diesel power, $13,600).

Small quantities of hazardous materials are burned more safely by first soaking the spilled material onto a combustible sorbent such as excelsior, ground corn cobs, or paper and then igniting the sorbent with a long excelsior train. Open burning is not recommended for organo-metallic compounds or highly halogenated substances.

5.2 Incineration is a high-temperature oxidation reaction between the hazardous substance and oxygen from the air under controlled conditions of residence time, temperature, turbulence, and oxygen concentration in a dedicated combustion chamber of the proper geometric configuration and size.

The desired end products of incineration are materials of greatly reduced toxicity, hazards, and reactivity and are typically CO_2, H_2O, and small quantities of HCl and SO_2. However, if the operating parameters are not carefully controlled, a broad spectrum of partially decomposed products results (e.g., partially oxidized organics and oxygenated organochlorines like phosgene).

Incineration is inappropriate for materials with significant concentrations of heavy metals (such as lead, mercury, and arsenic) and for those which decompose violently (like peroxides) unless the undesired characteristics are first modified by pretreatment. Ash left from the incineration process which contains concentrations of heavy metal or non-volatile inorganic salts must be treated as a hazardous material and disposed at a secured landfill.

Because of the potential hazards involved in transporting, handling, and incineration of hazardous materials, certain informaton regarding the spilled material must be obtained before incineration is attempted. Among these are:

- Human Toxicity
- Compound Reactivity (with air and water)
- Physical form (solid, liquid, sludge mixture)
- Thermal Stability
- Heat Value (Btu's per lb)
- Water Content
- Melting Point and Boiling Point (initial)
- Viscosity
- Inorganic salt, phosphorus, heavy metal, sulfur, chlorine, and bromine content

The impact on incineration as a disposal method is dictated by the combined impact of all these characteristics. Expert consultation is advised for evaluating these relations and their significance.

Liquids are normally transported to the incinerator in tank-trucks or drums. Thin sludges can be atomized and transported in a similar fashion. If the sludges cannot be atomized, they must be treated as solids. Solids can often be transported to the incinerator in fiber drums which can be burned in many systems. Metal drums can often be charged directly into some systems, also. If the amount of solid material makes containerization impractical, dump trucks may have to be employed. However, a means must be available to feed the material into the incinerator without endangering personnel.

There are several types of incinerator systems, each with design characteristics enabling it to handle varying forms of waste materials. The primary designs are fixed bed and moving bed incinerators. Fixed bed incinerators do not provide movement of the charge during incineration and generally do not provide the complete combustion capabilities of the moving bed designs. The major advantages of fixed bed incinerators is their availability. Moving bed incinerators provide a mechanism to move the charge during combustion. The most common moving bed systems are rotary kiln, multiple hearth, fluidized bed, and liquid injection. These are discussed briefly below.

Rotary kiln incinerators are generally refractory-lined, cylindrical shells mounted at a slight angle from horizontal. The charged material is moved by rotation of the cylinder, the speed of which will determine residence time and mixing with combustion air. Rotary kilns are designed to handle a wide variety of waste feeds, solids, liquids, some bulk wastes contained in fiber drums, and sludges. They have been used by industry to destroy solid and liquid combustible wastes, chemical warfare agents, and munitions.

Multiple hearth incinerators consist of vertical refractory-lined steel cylinders with multiple horizontal hearths or levels. The waste material is fed in at the top and then cascades to each lower hearth level until it is completely burned by the time it reaches the bottom of the incinerator. These systems are used almost exclusively for incineration of municipal sewage sludge and low hazard wastes. They are not well suited to incineration of highly toxic wastes for two reasons. First, they exhibit cold spots, and second since the waste is fed into the system near the top and exhaust gases also exit from the top, a potential exists for volatile gases to short-circuit the incineration and exit via the top.

Fluidized bed incineration systems maintain turbulent motion in a bed of very hot inert granules, such as sand, providing rapid and thorough heat transfer to injected fuel and waste. Air forced up through a perforated plate maintains the turbulent motion in the bed. Wastes are injected rapidly in small amounts and mix with the bed material, which transfers heat to the waste. The largest drawback of this system is limited capacity and limited range of applicable waste feed.

Liquid injection incinerators are the most widely used system for hazardous waste disposal. As the name implies, these incinerators can accommodate only liquids, slurries, and low viscosity sludges (<10,000 SSU). The principle of operation requires that the liquid waste be completely converted to a gas prior to combustion, thus limiting the droplet size to 40 microns or less. Wastes are atomized by specially designed nozzles. While nozzle designs tend to be waste specific, systems exist which are capable of handling many different kinds of wastes (such as motor and industrial oils, emulsions, solvents, lacquers, and organic chemicals including pesticides and chemical warfare agents).

In general, incineration is the most effective way to destroy a wide range of hazardous materials with minimum impact on the environment. It is the method of choice for disposal of nonbiodegrdable organics and restricted organics.

Additional information on incineration is given below.

Limitations: Equipment is more costly and complicated to operate than other alternatives. Incineration facilities may not be immediately available. It may not be ultimate disposal as the resulting ash may contain toxic materials.

Requirements: Ash must be disposed in all cases. If nontoxic, disposal in a sanitary landfill is adequate; if toxic, a secured landfill must be used. Air pollution control equipment must be employed to heat gaseous combustion products. Services of an experienced consultant are needed before attempting incineration of hazardous materials.

Availability: Incineration is a relatively common disposal method, and facilities providing incineration services are wide spread. Estimates of the numbers of various types of incinerators in current service are given below.

Rotary Kiln - 42 in service under interim status

Multiple Hearth - Widely used for coal and municipal waste combustion - no estimate of total number of units

Fluidized Bed - 9 in service

Liquid Injection - 219 in service

In addition to the above land-based systems, 2 ship-based incineration systems are currently available. Cement kiln systems have also been used for waste disposal. National kiln capacity is estimated at 41.5 million tons/year.

Costs: Costs charged at commercial facilities will vary depending upon the type of incineration and the waste type. Estimated average costs are as follows:

Type of Waste	cost ($/ton)[a]
Drummed	$120 - $400
Liquids	$ 53 - $400
Relatively clean liquids with high BTU value	$ 13 - $53[b]
Solids and/or highly toxic liquids	$395 - $791

a. (1981 $)
b. Some cement kilns and light manufacturers pay for these relatively clean, high energy value wastes.

5.3 Wet air oxidation involves the aqueous phase oxidation of reduced inorganic and organic substances with air under elevated pressure at moderate temperatures. It could be suitable for the treatment of high-strength or toxic organic wastes and of nonbiodegradable organic wastes. With proper combinations of operating conditions (residence time, temperature, and pressure) any degree of oxidation can be achieved, including complete destruction. The process has been used, however, to reduce the chemical oxygen demand (COD) of a waste stream by 60-90%, the remainder of which is biodegradable.

A small amount of waste gas is produced during the oxidation process but due to low temperatures (250-450°F) it is largely elemental nitrogen and carbon dioxide. Nitrogen dioxide, sulfur dioxide, and particulate emissions are not a problem. However, scrubbing of the waste gases may still be necessary. For example, this is true if cyanides or nitriles are present in the treated waste (which results in the formation of ammonia during oxidation).

Like incineration, wet air oxidation is a thermal oxidation process; but, unlike incineration, wet air oxidation is relatively energy conserving. For the process to be autogenous the COD of the waste feed must be at least 15,000 ppm (as opposed to 300,000-400,000 ppm for autogenous incineration). This means that once the oxidation reaction has been started it will be thermally self-sustaining with the proper waste feed. Significant power demand, however, occurs for air compression and pumping the waste into the reactor. Wet air oxidation is more capital-cost intensive than incineration, however. In general, if the waste material can be burned directly without evaporation or other dewatering processes, then dry incineration will almost always be cheaper.

Additional information on wet air oxidation follows.

Availability and Costs: Equipment associated with wet air oxidation is available from manufacturers, but each application requires a thorough evaluation before utilization. Complete oxidation systems are also available. Capital costs for a 54,000 l/day (14,400 gpd) titanium constructed unit is estimated to be $1.25 - 1.5 million. Operating costs are estimated at $15/hr for fuel and $0.025/gallon of waste.

5.4 Pyrolysis is a combustion process that proceeds with a stoichiometrically insufficient oxygen supply. Calcination, perhaps that most commonly analyzed form of pyrolyis, is the extreme case whereby aqueous mixtures and sludges are converted into solids by thermal decomposition without any interaction with oxygen (in contrast to incineration).

Pyrolysis facilities generally consist of two stages, a pyrolyzing chamber and a fume incinerator. The latter is used to destroy volatile components given off during the pyrolysis reaction. Pyrolytic combustion avoids volatilization of inorganics (including heavy metals) by forming a solid, easy-to-handle char. Pyrolysis units have been used to destroy chemical warfare agents and kepone-laden sludge.

Calcination is a well-established process that has many industrial and waste treatment applications. The primary advantage of this process is that several actions can often be performed simultaneously in a single step, i.e., concentration of waste, destruction, and detoxification. Calcination can be used for treatment of organic and organo-metallic compounds, and inorganic salts that contain a volatile component.

The first reaction which occurs during calcination is that water contained in the waste is vaporized leaving a granular or compacted solid. If reaction temperatures are sufficiently high, the next reaction will drive off volatile materials from the solids to form oxides. Upon further heating the granular material may be sintered into a solid mass. On still further heating certain material will melt or fuse into a glass-like material (see Section 6.6.1). Additives such as silicates, borax, or phosphates can be added to improve this process. As with incineration there are several types of calciners including open hearth, rotary kiln, and fluidized bed designs (see Section 6.1).

Calcination has many industrial applications, such as smelting metal ores, manufacture of cement and lime, and treatment of oily petroleum sludges. As a waste treatment method, current uses include treatment of liquid radioactive wastes and refinery sludges. The major disadvantages of calcination are: 1) it is very energy intensive requiring 1-3 million BTU/ton of dry material and 2) it produces emissions of hazardous gaseous pollutants (such as nitrogen dioxide, sulfur dioxide, and particulates) which require fairly extensive air treatment systems. Fuel costs can be reduced if the waste material contains an organic fraction; however, the need for air pollution control equipment cannot be eliminated.

In general, calcination should be considered a viable waste treatment method whenever a one-step process is required to handle a complex waste. This is particularly true if the waste contains both organic and inorganic components. Calcination can prove very useful whenever landfill material of low leachability is required. It must be remembered, however, that the calcine may still be toxic unless the toxic component was destroyed or removed as a volatile material during the calcination.

Availability: Suitable equipment in the form of multiple hearth, rotary kiln, and fluidized bed calciners are commercially available from several manufacturers. Mobile units are not commercially available yet.

Costs: Estimated capital cost for a 6,500 gal/hr (10% solid) calcination system is \$2.9 million (1978 \$), including costs for filtration and air pollution control equipment. Operating costs are estimated to be \$17.95/1000 gallons of waste treated (1978 \$).

5.5 Landfill: Landfilling is the burial of waste, in excavated trenches or cells, in either bulk or containerized form in a permitted waste disposal site. Federal regulation define pretreatment requirements for wastes that contain free liquids and wastes that are ignitable, reactive, and/or corrosive. Containerized liquids cannot be landfilled unless the liquids are rendered nonflowing (by adding absorbent material to the container, for example). Bulk liquids can be disposed of into landfills with synthetic linings and leachate collection systems. Many states are prohibiting disposal of various hazardous wastes, particularly liquid hazardous wastes, to reduce the potential for hazardous substances migrating from the disposal site. Landfill facilities often establish their own standards for the types and forms of wastes that they will accept in accordance with the landfill permits and state regulations. For instance, many waste handlers have established strict prohibition against burial of liquids, in bulk or in containers. Others may require specific pretreatment of wastes such as solidification and stabilization before accepting these wastes for burial. These are important facts to consider before choosing landfill as a disposal method for hazard materials.

A potential disadvantage to the use of landfill for disposal is the costs associated with excavation/containerization of the spilled material and/or contaminated media. Transportation to the nearest landfill disposal site may be prohibitive. Additional costs may also be realized if the disposal facility requires pretreatment of the waste stream before accepting it. Another major disadvantage to landfill disposal(as opposed to on-site or even in situ alternatives) is the additional exposure and subsequent danger to cleanup personnel and the environment due to the fact that the excavation/containerization/transportation/burial process requires excessive handling of the spilled waste.

Additional information on landfill disposal is given below.

Availability: Estimated number of landfill facilities nationwide during 1981 is 270, of which 25% are classified as commercial, off-site landfill facilities.

Costs: Landfill costs (1981 \$) for drummed waste is estimated to be \$168 - 240/ton and for bulk waste \$55-83/ton. Transportation cost is estimated to be \$0.15/ton mile.

5.6 Deep-well injection of liquid wastes into subsurface rock is a technology that takes advantage of the porosity of sedimentary strata to hold the liquid waste. Underground injection entails drilling a well to a depth required to intersect an appropriate geologic formation and injecting liquid waste into the well with sufficient pressure to displace native fluids. Certain criteria must be met before particular strata can be considered suitable for injection.

1) no value as a resource

2) sufficiently porous and voluminous to accept waste

3) sealed above and below by formations which will prevent migration of waste

4) located in an area with little seismic activity

A wide range of liquid wastes can be disposed of using deep-well injection. Characteristics of a liquid waste which limit the applicability of injection are:

1) high suspended particulate content

2) high viscosity

3) chemical incompatibility with formation or formation fluids

Well injection is applicable to dilute and concentrated acid or alkaline solutions, heavy metal and inorganic solutions, chlorinated hydrocarbons, solvents, and high COD or BOD organic solutions.

Current estimates of the number of wells in use for disposal of hazardous industrial chemicals is 159. Sixty percent of these are located in EPA Region VI (Texas, Oklahoma, New Mexico, and Louisiana) which means transportation costs to a well site may be prohibitive to other EPA regions.

Costs: (1981 $)

Oily waste water - $0.06 - $0.15/gal or $16 - $40/ton
Toxic rinse water - $0.05 - $1/gal or 132 - $264/ton

5.7 Other processes described in this section are currently being studied and evaluated for use in hazardous waste disposal. Pilot plant technology exists for several of these processes. These processes are not considered feasible or cost effective at this time, however.

5.7.1 Vitrification

Vitrification is a solidification process which entails glassification of excavated contaminated soils, sediments, and extremely dangerous or radioactive wastes. By combining the wastes with silicate materials, it is possible to fuse the mixture into glass at elevated temperatures (1100 to 1500° C). This method is generally assumed to be a safe, permanant disposal method due to only very slow leaching by naturally-occurring water. This high degree of containment of wastes together with the fact that the additives are relatively inexpensive are the primary advantages to this process. The main disadvantages are: the process is energy intensive, some waste constituents may vaporize before they combine with molten silicates in the glass, and specialized equipment and trained personnel are needed.

5.7.2 Molten Salt Combustion

Molten salt combustion entails injecting hazardous waste mixed with air beneath the surface of a pool of molten sodium carbonate maintained at 800 - 1000° C. Organic materials are immediately oxidized and inorganics such as halogens, sulfur, phosphorus and arsenic form salts which remain in the molten sodium carbonate rather than being released as volatile gases. Unlike other incinerator processes, essentially no acidic gaseous pollutants are emitted from this process. The ash and salts which accumulate in the melt can be removed by quenching the melt in water and then processing the sodium carbonate to remove the contaminants.

Tests conducted with a pilot scale molten salt reactor have effectively destroyed chemical warfare agents, PCBs, and chlorinated pesticides. The process is not suited for wastes with high ash contents (>20% ash) or for municipal wastes and sludges that are not particularly hazardous (for which less expensive disposal methods are available).

5.7.3 High Temperature Fluid Wall Reactor

This process utilizes electromagnetic radiation to heat the core of a reactor to radiant temperatures around 2200° C. The wastes are reduced to their elemental state by pyrolysis. Pilot studies of this process are currently in progress.

5.8.4 Plasma Reactor

A plasma reaction is an exothermic process whereby a hazardous substance is destroyed by a partially ionized gas produced by microwave discharge. With oxygen plasma, particularly under conditions of high power density, decomposition products are typically oxidized to stable compounds similar to those obtained from complete combustion.

Commercial plasma reactors are available; however, they are used for plasma ashing and other analytical applications and in the production of semi-conductors. Although this process is still under development for hazardous waste destruction, small, self-contained mobile plasma reactors may be commercially available in the near future.

SECTION 5

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APPENDIX A

GUIDELINES FOR SITE ASSESSMENT, ENTRY, AND CONTROL

An environmental incident (also referred to as an episode) involves a release or a threat of a release of hazardous substances, or it involves hazardous substances that pose an imminent and substantial danger to public health and welfare or the environment. Each incident presents special problems. Response personnel must evaluate these problems and determine an effective course of action to mitigate the incident. While each incident is unique, many commonalities exist. One commonality is that all incident response requires protecting the health and safety of the workers from any hazards present. Thus, the responders entering and controlling a hazardous incident site are to accomplish the following objectives:

- o Characterize the hazards that exist (or potentially exist) affecting the public health, the environment, and response personnel
- o Collect supplemental information to determine the safety requirements for personnel initially and subsequently entering the site
- o Conduct operations such that appropriate levels of protection are maintained
- o Control on-site and off-site contamination to reduce the possibility of exposure of personnel and the general public

The primary stages or phases involved in safely responding to an incident are (1) site assessment, (2) site entry, and (3) site control. Each of these stages has specific requirements for safety. For example, site assessment determines initial hazardous or potentially hazardous conditions. This information should be constantly updated throughout the response to reflect the acquisition of information on the known hazards. This appendix will describe the safety precautions needed for each of these stages of incident response operations. Specific details on personnel protective clothing and decontamination protocol are described in Appendices B and C, respectively. The information compiled for inclusion in Appendices A, B, and C was obtained from the following sources:

- o Flammable Hazardous Substances Emergency Response Handbook: Control and Safety Procedures, US EPA, 1982
- o Personnel and Response Equipment Decontamination - draft monograph - US EPA, 1981

- o Interim Standard Operating Safety Guides, US EPA, revised 1982

SITE ASSESSMENT

Site assessment should include an evaluation for site approach. This is essential to keep emergency control personnel out of the hazardous area until identification of the nature and degree of the hazards can be made and initial assessment completed. Before arrival at the release site, the responder should consider alternate surface routes, and the identified or suspected commodities involved. Once near the site, the site entrance requirement must be determined. Direct involvement in a hazardous substance incident may be justified if people trapped or exposed to undue risk precipitated by the incident can be reached without unreasonable risk to response personnel. The responder should ask the following questions: will the involvement of response personnel favorably affect the outcome? Are sufficient resources, personnel, and equipment available to deal with the incident?

Actions to be taken during initial assessment include:

- o Establish on-scene authority
    - Refer to control plan procedures and prearranged mutual aid agreements
    - Identify yourself and function; know your responsibilities
- o Keep traffic and spectators away
- o Keep sparks, fires, flares, cigarettes, etc., away from spill (do not let motor vehicles move through area of spill)
- o Use positive-pressure self-contained breathing apparatus (SCBA) and whole-body encapsulating suit or whole-body spliced suit if it is necessary to enter the site of a suspected but unidentified hazardous substance release. Reasonable cause for entering the site could be to rescue injured people, if it can be done safely. Approach site from upwind.

Proper risk assessment and control of a hazardous substance release requires the manager of initial response personnel to have as much information as possible about the hazardous substance(s) and hazard(s) involved in the accident. The nature of the hazardous substances and site conditions will, to a great extent, influence decisions on personnel deployment and application of response countermeasures. Therefore, identification of the hazardous substance(s) and site-specific parameters involved at the scene of the accident is exceedingly important.

A variety of methods can be used to identify a released hazardous substance. The initial attempt should involve remote means or methods, such as the use of field glasses and gas detectors, that can be employed at a safe distance from the site. Only after their use should the site be inspected first-hand for identification placards, documents, etc.

SITE ENTRY REQUIREMENTS

The initial on-site survey and reconnaissance, which may consist of more than one entry, is to characterize the immediate hazards (e.g., by monitoring) and, based on these findings, establish preliminary safety requirements. As data are obtained from the initial survey, the Level of Protection and other safety procedures are adjusted. Initial data also provide information on which to base further monitoring and sampling. No method can select a Level of Protection in all unknown environments. Each situation must be examined individually. While personnel protective equipment reduces the potential for contact with harmful substances, ensuring the health and safety of response personnel requires, in addition, safe work practices, site entry protocols, decontamination, and other safety considerations. Together, these protocols establish a combined approach for reducing potential harm to workers. Some general approaches can be given, however, for judging the situation and determining the Level of Protection required.

Personal Protective Equipment

Equipment to protect the body against contact with known or anticipated chemical hazards has been categorized by the U.S. EPA into four levels (A, B, C, and D) according to the degree of protection afforded. Level A protective equipment should be worn when the highest level of respiratory, skin, and eye protection is needed. Level B protective equipment should be selected when the highest level of respiratory protection is needed, but a lesser level of skin protection. Level B protection is the minimum level recommended on initial site entries until the hazards have been further defined by on-site studies and appropriate personnel protection utilized. Level C protective equipment should be selected after the type(s) of airborne substance(s) is known, the concentration(s) is measured, and the criteria for using air-purifying respirators are met. Level D protective equipment should not be worn on any site with respiratory or skin hazards. It is primarily a work uniform providing minimal protection.

The Level of Protection selected should be based primarily on:

- Type(s), toxicity, and measured concentration(s) of the chemical substance(s) in the ambient atmosphere

- Potential or measured exposure to substances in air, splashes of liquids, or other direct contact with material due to work being performed

In situations where the type(s) of chemical(s), concentration(s), and possibilities of contact are not known, the appropriate Level of Protection (A and B) must be selected based on professional experience and judgment until the hazards can be better characterized. Additional information on the specific equipment requirements is given in Appendix B.

Monitoring

Of concern to personnel are atmospheric conditions that could affect their safety. These conditions are airborne toxic substances, combustible gases or vapors, lack of oxygen, and, to a lesser extent, ionizing radiation. The primary type of monitoring that is necessary for initial response and for site entry and control includes periodic and peripheral ambient monitoring. Information on the atmospheric monitoring equipment and atmospheric hazard guidelines is identified in Table A-1. It is imperative that personnel using monitoring instruments be thoroughly familiar with their use, limitations, and operating characteristics. All instruments have inherent constraints in their ability to detect and/or quantify the hazards for which they were designed. Unless trained personnel use instruments and assess data readout, air hazards can be grossly misinterpreted, endangering the health and safety of response personnel. In addition, only intrinsically safe instruments should be used, until the absence of combustible gases or vapors can be confirmed.

Priority to Initial Entry

Monitoring Of immediate concern to initial entry personnel are atmospheric conditions that could affect their immediate safety. These conditions are airborne toxic substances, combustible gases or vapors, significant change in normal oxygen levels, and ionizing radiation. Priorities for monitoring these potential hazards before entry should be established after a careful evaluation of conditions. When the type of material involved in an incident is identified and its release into the environment suspected or known, the material's chemical/physical properties and the prevailing weather conditions may help determine the order of monitoring. An unknown substance or situation presents a far more difficult monitoring problem.

In general, before entering poorly ventilated spaces (e.g., buildings, ship's holds, boxcars, or bulk tanks) test for combustible vapors/gases and oxygen-deficient atmosphere. Toxic gases/vapors and radiation, unless known not to be present, should be measured as the next priority. If team members must then enter, they should wear, as a minimum, Level B protective equipment.

For open, well-ventilated areas, combustible gases and oxygen deficiency are lesser hazards, and require lower priority. However, because site areas of relatively low elevation (such as ditches and gullies) and downwind areas may have combustible gas mixtures, or toxic vapors or gases, or may lack sufficient oxygen to sustain life, entry teams should approach and monitor from the upwind direction whenever possible.

Periodic Monitoring

The purpose of monitoring surveys made during the initial site entry phase is to make a preliminary evaluation of atmospheric hazards. Sometimes the information obtained may be sufficient to preclude additional monitoring--for example, a chlorine tank may be determined not to be releasing chlorine. However, when hazardous substances are detected during the initial site survey, a comprehensive program must be established for monitoring, sampling, and evaluating hazards for the duration of site operations. Since site activities (and the effects of weather conditions on them) change, a continuous program to monitor atmospheric changes must be implemented utilizing

TABLE A-1. ATMOSPHERIC HAZARD GUIDELINES

Monitoring Equipment	Hazard	Ambient Level	Action
Combustible gas indicator	Explosive atmosphere	<10% LEL	Continue investigation.
		10%-20%	Continue on-site monitoring with extreme caution as higher levels are encountered.
		>20% LEL	Explosion hazard; withdraw from area immediately.
Oxygen concentration meter	Oxygen	<19.5%	Monitor wearing SCBA. NOTE: Combustible gas readings are not valid in atmospheres with <19.5% oxygen.
		19.5%-22%	Continue investigation with caution. SCBA not needed, based on oxygen content alone.
		>22.0%	Discontinue inspection; fire hazard potential. Consult specialist.
Radiation survey	Radiation	<3 mR/hr	Continue investigation. If radiation is detected above background levels, this signifies the presence of possible radiation sources; at this level, more thorough monitoring is advisable. Consult with a health physicist.
		>10 mR/hr	Potential radiation hazard; evacuate site. Continue monitoring only upon the advice of a health physicist.
Colorimetric tubes	Organic and inorganic vapors/gases	Depends on species	Consult standard reference manuals for air concentrations/toxicity data.
HNU photoionizer	Organic vapors/gases	1) Depends on species	Consult standard reference manuals for air concentrations/toxicity data.
		2) Total response mode	Consult EPA Standard Operating Procedures. Cross readings above 500 ppm require maximum level of protection.
Organic vapor analyzer	Organic	1) Depends on species	Consult standard reference manuals for air concentrations/toxicity data.
		2) Total response mode	Consult EPA Standard Operating Procedures.

combination of stationary sampling equipment, personnel monitoring devices, and periodic area monitoring with direct-reading instruments.

Peripheral Monitoring

Whenever possible, atmospheric hazards in the areas adjacent to the on-site zone should be monitored with direct-reading instruments, and air samples should be taken before the initial entry for on-site monitoring. Negative instrument readings off-site should not be construed as definite indications of on-site conditions, but only another piece of information to assist in the preliminary evaluation.

SITE CONTROL REQUIREMENTS

A site must be controlled to reduce the possibility of (1) exposure to any contaminants present, and (2) contaminant transport by personnel or equipment from the site. The possibility of exposure or translocation of substances can be reduced or eliminated in a number of ways, including:

- Setting up security and physical barriers to exclude unnecessary personnel from the general area
- Minimizing the number of personnel and equipment on-site consistent with effective operations
- Establishing work zones within the site
- Establishing control points to regulate access to work zones
- Conducting operations in a manner to reduce the exposure of personnel and equipment and to eliminate the potential for airborne dispersion
- Implementing appropriate decontamination procedures

To minimize the transfer of hazardous substances from the site (due to site activities), contamination control procedures are needed. Two general methods are used: establishing site work zones and decontaminating people and equipment.

Work Zones

One method of preventing or reducing the migration of contamination is to delineate zones on the site where prescribed operations occur. Movement of personnel and equipment between zones and onto the site itself would be limited by access control points. By these means, contamination would be expected to be contained within certain relatively small areas on the site, and its potential for spread minimized. Three contiguous zones are recommended:

Zone 1: Exclusion Zone (including the "Hot" Zone)

Zone 2: Contamination Reduction Zone

Zone 3: Support Zone

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Zone 1: Exclusion Zone (including the "Hot" Zone)

Zone 2: Contamination Reduction Zone

Zone 3: Support Zone

Zone 1: Exclusion Zone.

The Exclusion Zone, the innermost of three concentric areas, is the zone where contamination does or could occur. All people entering the Exclusion Zone must wear prescribed Levels of Protection. An entry and exit checkpoint must be established at the periphery of the Exclusion Zone to regulate the flow of personnel and equipment into and out of the zone and to verify that the procedures established to enter and exit are followed.

Zone 2: Contamination Reduction Zone.

Between the Exclusion Zone and the Support Zone is the Contamination Reduction Zone, which provides a transition between contaminated and clean zones. Zone 2 serves as a buffer to further reduce the probability of the clean zone becoming contaminated or being affected by other existing hazards. It provides additional assurance that the physical transfer of contaminating substances on people, equipment, or in the air is limited through a combination of decontamination, distance between Exclusion and Support Zone, air dilution, zone restrictions, and work functions.

Zone 3: Support Zone.

The Support Zone, the outermost part of the site, is considered a noncontaminated or clean area. Support equipment (command post, equipment trailer, etc.) is located in the zone; traffic is restricted to authorized response personnel. Since normal work clothes are appropriate within this zone, potentially contaminated personnel clothing, equipment, and samples are not permitted, but are left in the Contamination Reduction Zone until they are decontaminated.

Decontamination

Removing contaminants from response team personnel, their clothing, and equipment is a major function of site control during the cleanup of a hazardous material spill or hazardous waste site. Contamination is defined as the presence of harmful chemicals that are capable of producing adverse health effects to humans through absorption, inhalation, and/or ingestion. Decontamination is the complete or partial removal, neutralization, or destruction of the harmful contaminating chemical(s). Personnel responding to hazardous substance incidents may become contaminated in a number of ways, including:

- Contacting vapors, gases, mists, or particulates in the air
- Being splashed by materials while sampling or opening containers
- Walking through puddles of liquids or on contaminated soil
- Using contaminated instruments or equipment

Protective clothing and respirators help prevent the wearer from becoming contaminated or inhaling contaminants, while good work practices help reduce contamination on protective clothing, instruments, and equipment.

A decision to decontaminate clothing, equipment, or other contaminated items, or to destroy them, is purely one of economics. If the cost of decontamination to an acceptable level exceeds the replacement cost of the contaminated items plus the costs associated with their disposal, obviously disposal is warranted. However, in the case of certain cleanup items that are quite expensive, e.g., air monitors, totally encapsulating suits, earth-moving equipment, decontamination may be quite economical. The decision to destroy contaminated equipment and clothing or to decontaminate for reuse should be made by the owners of the contaminated items and those bearing the cost of decontamination.

The ability of a contaminated item to withstand the decontamination cycle will, of course, enter into the decontaminate/destroy decision. If a protective garment is contaminated with a chemical that can only be removed with a decontamination solution that will severely damage the garment, then disposal should be considered. Additionally, if a piece of equipment or clothing is constructed of material that tends to temporarily retain chemicals because of adsorption and/or retention in surface irregularities (thus preventing easy or thorough decontamination), then disposal is indicated.

When decontamination is justified an area is defined for performing the decontamination. If disposal of contaminated clothing, equipment, etc. is warranted, a similar area must be designated for doffing clothing, body decontamination, and storing the contaminated items for later disposal.

The equipment, solutions, and procedures required for decontamination depend on the degree and nature of the contamination. If the extent and/or type of contamination is unknown, then the decontamination equipment and procedures must be extensive. The decontamination solution(s) must be effective against an array of hazardous chemicals. Knowing the extent and type of contamination might allow for use of a reduced level of effort to achieve an acceptable level of decontamination. See Appendix C for further details on decontamination protocol.

APPENDIX B

SUGGESTED GUIDELINES FOR SELECTING CHEMICAL PROTECTIVE CLOTHING

This appendix is designed to assist the responder in selecting chemical protective clothing for dealing with hazardous substance releases into the environment. The responder must ascertain quickly and effectively what protective clothing (as well as respiratory protection) will be required to assure safe and corrective action. The hazardous properties of chemical substances necessitate the use of extremely reliable chemical protective clothing. A search of available protective clothing, however, reveals a sizable array of different protective suits, manufactured in an assortment of designs and styles, employing various fabrics and elastomers, with a host of different operational and performance characteristics. Thus, the information provided herein is designed to assist response personnel in selecting appropriate chemical protective clothing; however, it should be noted that a first-hand experimental and/or field evaluation of the protective clothing would provide better data then derived from a desk-top or literature evaluation.

Selection of the proper protective clothing is based on a number of factors including such site-specific parameters as the types of hazards involved, chemical(s) released, concentration levels of exposure, potential route(s) of entry by the substance(s) into the human body, and conditions at the site. These site-specific parameters will fix the level of protection required which, in conjunction with predetermined clothing compatibility information and suit performance data, will provide the means for selection of the proper protective clothing.

The levels of protection usually used by the EPA to describe different ensembles of protective clothing and their criteria for use are described in the following paragraphs.

Level A - Maximum Available Protection

1. When the type(s) and concentration(s) of toxic substances are known and require the highest level of combined protection to the respiratory tract, skin, and eyes, such as is found with:

    A. Atmospheres that are "immediately dangerous to life and health" (IDLH). (IDLH values can be found in the NIOSH/OSHA's "Pocket Guide to Chemical Hazards" and/or other references.)

B. Known atmospheres or potential situations that would affect the skin, eyes, or respiratory system, or could be absorbed into the body through these surfaces. Standard reference books should be consulted to obtain concentrations hazardous to skin, eyes, or mucous membranes from situations involving:

  o Generated vapors

  o Splashing liquids
  o Oxygen deficient atmospheres

2. At sites where the type(s) and/or potential concentration(s) of toxic substances are unknown.

   A. Unless strong contraindications are available, the site should be presumed to present hazards to the respiratory system, skin, and eyes.

      o Total vapor readings above 500 ppm on field instruments indicate significant hazards

      o Areas of concern would include enclosed areas such as buildings, railroad cars, shipholds, etc.

   B. Contraindications might be indicated by:

      o Reliable, accurate historical data

      o Open, unconfined area, with minimal probability of vapor(s) present or splashing liquids

3. Level A Protection Equipment: Suit is a sealed, full-body, totally encapsulating design with supplied air, i.e., positive-pressure self-contained breathing apparatus (SCBA) (MSHA/NIOSH approved). Individual parts of the suit include: inner gloves (tight-fitting and chemical-resistant), outer gloves (chemical-resistant), boots (chemical-resistant, with steel toe and shank), and two-way radio communications. Full-body encapsulating suits are produced and used in order to provide a full-body protection for dealing with those substances that may be hazardous to humans. The overall aim of this type of clothing is to isolate the wearer from the surrounding atmosphere. Individual parts of the suit are either sealed together, or provide very long overlaps. Many of the encapsulating suits are designed to provide protection from chemical hazards, while others provide protection against fire. No commercially available suit can provide complete protection against both chemical and fire hazards.

Level B - Complete Protection

1. When the type(s) and concentration(s) of hazardous substances are

known and require the highest degree of respiratory protection, but a lower level of skin and eye protection.

A. Atmospheres with concentrations of known substances greater than protection factors associated with full-face, air-purifying respirators and which do not present a cutaneous or percutaneous hazard to the small, unprotected areas of the body

B. Total readings ranging from 5 to 500 ppm on field instruments of vapor levels that do not contain suspect high levels of toxic substances affecting skin or eyes

2. When potential exposure to the body parts not protected by a fully encapsulating suit (primarily neck, ears, etc.) is highly unlikely.

   A. Known absence of cutaneous or percutaneous hazards

   B. Activities performed preclude splashing liquids

3. Level B protection is recommended as the lowest level of protection for initial entries until the hazards have been further identified and defined by monitoring, sampling, and other reliable methods of analysis, and the personnel protection equipment commensurate with these findings can be utilized.

4. Level B Protection Equipment: Suits can be a one-piece or two-piece design, usually with filtered air supply, but a life support system can be added as needed. Additional individual parts of the suit include: non-impact protective draped hood, chemical protective boots (with steel toe and shank inside and heavy rubber throwaway outside), protective gloves (which are often attached by overlapping rubber bands), and two-way radio under suit. Hard hat, face shield, and coveralls are optional. Whole-body encapsulating suits are designed to protect individuals from hazards that do not require full body protection. Life support systems are not normally included in these suits, but can often be added.

Level C - Selective Protection

1. Sites known to contain potential hazards not to exceed:

   A. Air concentrations of material not requiring a protection factor greater than that afforded by a full-face mask (normally considered to be 10)

   B. Body exposure to unprotected areas (head, face, neck, etc.) less than any amount that will cause harm

   C. Total vapor reading between 0 and 5 ppm above background on field instruments

D. No evidence of acute or chronic effects to exposed personnel

2. At incidents where the concentration of substances in the air are unknown, but the criteria for selecting Levels A and B indicate Level C would be an acceptable choice

3. Air monitoring is mandatory

4. Protection Equipment: Chemical-resistant clothing (coveralls, hooded two-piece chemical splash suit), full-face, air-purifying respirator (MSHA/NIOSH approved), chemical protective gloves (outside), chemical protective boots (with steel toe and shank), escape mask, and two-way radio communications. Hard hat, face shield, outer heavy rubber throwaway boots and inner surgical gloves are optional. Partial body clothing is widely manufactured and includes approximately 150 different styles of coveralls, work gloves, boots, aprons, and goggles. This clothing is utilized when minimal-type protection is warranted. The purpose often is to keep one's own clothing free from any type of work contamination.

Level D - General Protection

1. No indication of airborne health hazards present

2. No gross indications above background on field instruments

3. Periodic air monitoring is recommended

4. Protection Equipment: Chemical-resistant coveralls, boots/shoes, escape mask, safety glasses. Outer boots, hard hat, face shield, and gloves are optional.

APPENDIX C

PERSONNEL AND RESPONSE EQUIPMENT DECONTAMINATION

The information contained herein was compiled from a number of sources and this appendix is intended to provide general information on decontamination of personnel, clothing, and equipment used for spill cleanup. The user must tailor the information in this appendix to suit the specific conditions present at a hazardous spill.

FIELD DECONTAMINATION PROTOCOLS

Decontamination Zone

The decontamination zone (sometimes called the contamination reduction zone) is the area where decontamination takes place. It is located upwind of the exclusion area (in which prescribed levels of protection must be worn) but downwind of the support area. The support area is considered a noncontaminated area and contains the command post and other facilities required to support the site activities. No person or piece of equipment may enter the support area after being in the exclusion area without first being decontaminated (if required) and certified clean by the safety control officer present in the decontamination zone.

Determination of the decontamination zone-exclusion area boundary is dependent on a number of factors relating to the hazards involved, and to the terrain, etc. The establishment of the decontamination zone-support area boundary is based primarily on the amount of space required by the decontamination operation. If large pieces of equipment require decontamination, then the area of the decontamination zone boundaries should be based on the best information available, and with the greatest concern being the safety of the personnel involved in the cleanup and decontamination operations.

Personnel Decontamination Station (PDS)

The personnel decontamination station (PDS) is the area within the decontamination zone where personnel and personnel protective clothing and equipment are decontaminated. The extent of the PDS is dictated by the nature of the chemical hazard and the requirements for decontamination.

When the hazard is known, the PDS should be set up for decontaminating to an extent which will assure that the personnel and personnel protective equipment are free of the specific identified hazardous substance(s). This may require an extensively outfitted PDS, as would be required in the case of contamination with a carcinogenic pesticide, or a minimally equipped PDS, as in the case of acid contamination. When the hazard is unknown, the PDS should always be set up for maximum decontamination. A maximum decontamination PDS might be set up as shown in Figure C-1. Following are descriptions of each station shown in Figure C-1.

Station A:	A plastic ground sheet on which field equipment is placed by returning members of the work party
Station B:	A wash tub (or wading pool) filled with decontamination (decon) solution A A second wash tub filled with rinse solution A third wash tub filled with decon solution B A fourth wash tub filled with rinse solution Each wash tub should be equipped with a large sponge and brush
Station C:	A bench or stool for personnel to sit on during removal of booties A 10-gallon pail with plastic liner where disposable boot covers are discarded
Station D:	Two 10-gallon buckets filled with decon solution A and B, respectively
Station E:	A 10-gallon bucket filled with rinse solution
Station F:	A 32-gallon trash can with plastic liner
Station G:	A plastic ground sheet for SCBA drop
Station H:	A bench or stool for personnel A 32-gallon trash can with plastic liner
Station I:	A field shower setup
Station J:	A redressing and first-aid station

The SCBA tank changeover point is between stations E and F. If personnel are returning to the exclusion area after the tank changeover, decontamination through Station E is required, after which decontaminated booties should be donned before reentry. Note: An adequate supply of air must be provided for cleanup personnel during SCBA tank changeovers.

Equipment Decontamination Station

Two equipment decontamination stations (EDSs) are necessary during cleanup operations involving heavy earth-moving equipment, one for decontamination of hand-held tools and equipment, and one for decontaminating the heavy equipment.

Small Equipment

A single EDS will suffice for those operations requiring only small hand-held tools and equipment. The EDS for small tools and equipment may parallel the PDS. As seen in Figure C-1 (and which would be a component of the PDS for a less extensive decontamination operation), an equipment drop area exists inside the exclusion area where personnel leaving the exclusion area for the PDS deposit any hand-held articles (Station A). Figure C-2 shows how a typical EDS for small items might be set up.

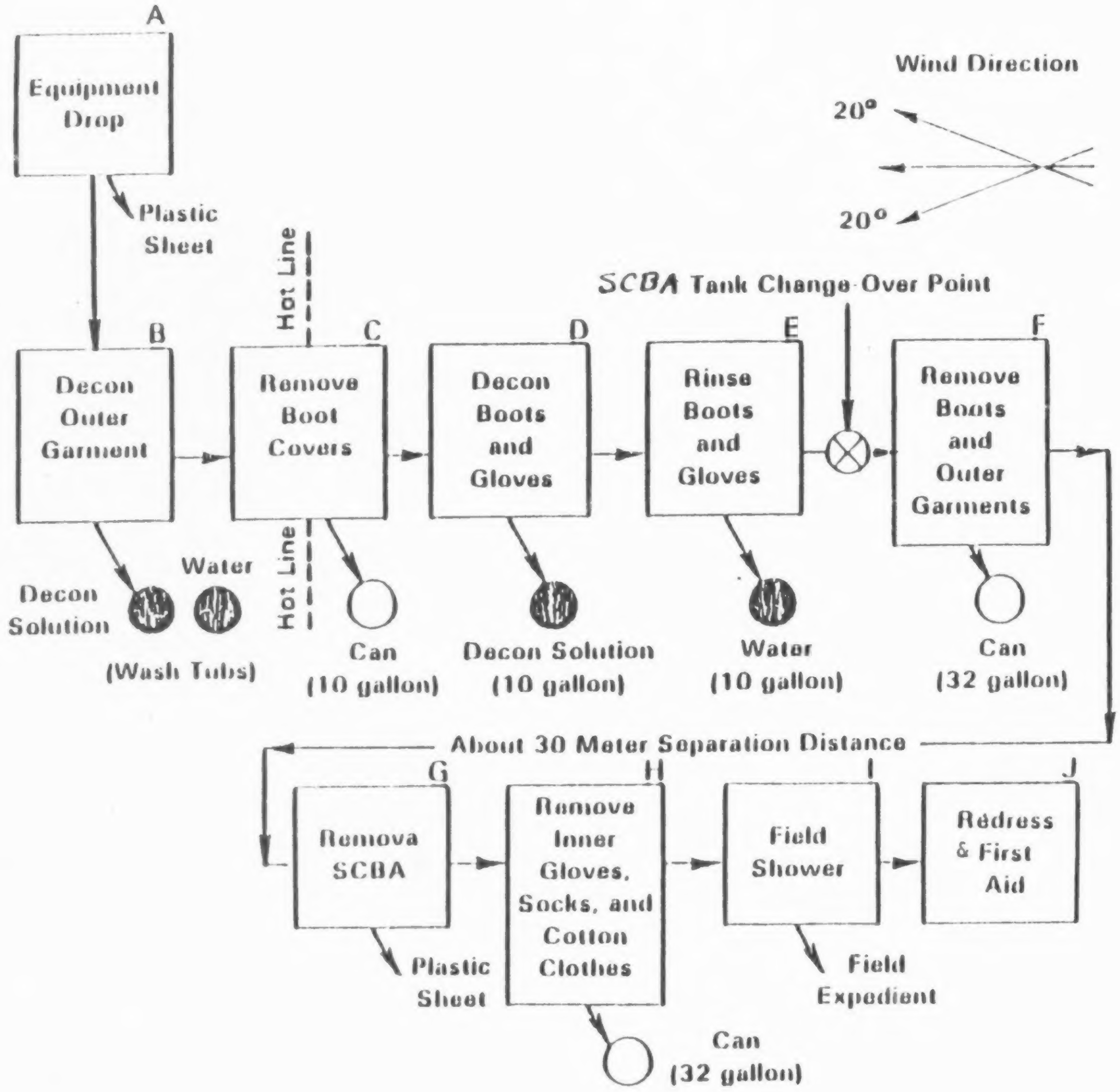
Wind Direction
20°
20°
A
Equipment Drop
Plastic Sheet
B
Decon Outer Garment
Decon Solution
Water
(Wash Tubs)
Hot Line
Hot Line
C
Remove Boot Covers
Can (10 gallon)
D
Decon Boots and Gloves
Decon Solution (10 gallon)
E
Rinse Boots and Gloves
Water (10 gallon)
SCBA Tank Change-Over Point
F
Remove Boots and Outer Garments
Can (32 gallon)
About 30 Meter Separation Distance
G
Remova SCBA
Plastic Sheet
H
Remove Inner Gloves, Socks, and Cotton Clothes
Can (32 gallon)
I
Field Shower
Field Expedient
J
Redress & First Aid

Figure C-1. Maximum layout of personnel decontamination station.

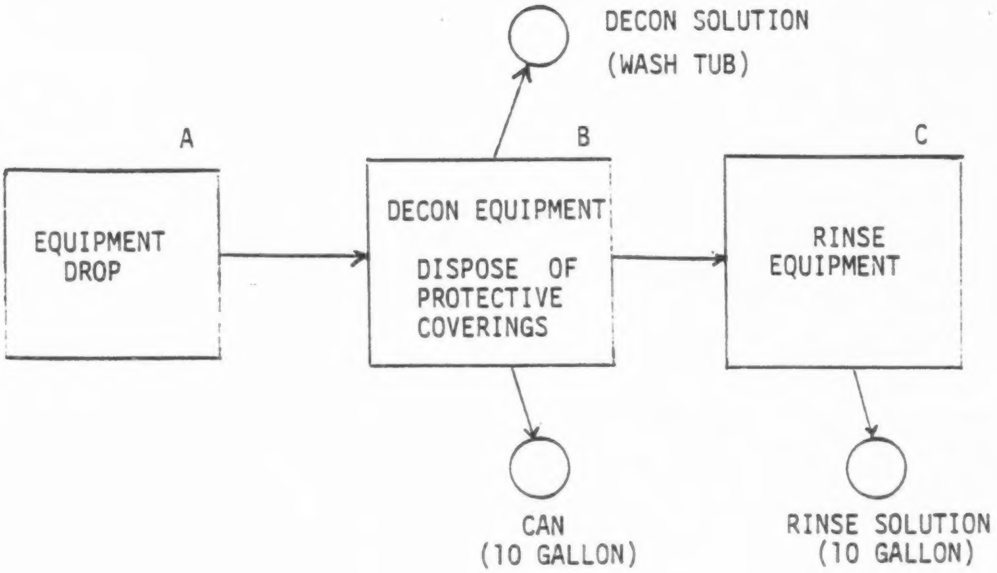
DECON SOLUTION
(WASH TUB)
A
B
C
EQUIPMENT DROP
DECON EQUIPMENT
DISPOSE OF PROTECTIVE COVERINGS
RINSE EQUIPMENT
CAN
(10 GALLON)
RINSE SOLUTION
(10 GALLON)

Figure C-2. Proposed EDS for Small Equipment

Following are descriptions of each station shown in Figure C-2.

Station A:	A plastic ground sheet on which field equipment is placed by returning members of the work party
Station B:	A wash tub filled with the decon solution. A can for disposal of equipment protective coverings
Station C:	A wash tub filled with rinse solution

As with the PDS, the extent of the EDS operation is governed by the nature of the hazard, if known. If unknown, then the EDS equipment and procedures should be maximized to assure rendering the equipment harmless, assuming the greatest possible contamination hazard.

Large (Heavy) Equipment

Ideally, the EDS for heavy equipment should be located where runoff from the decontamination procedures can be easily contained. This is particularly important for equipment contaminated with dangerous levels of toxic residue. The EDS could be a concrete or asphalt surface (e.g., a roadway) upon which soil dikes or foamed-in-place barriers are applied to contain the potentially contaminated runoff. Alternatively, a pit lined with a thick compatible elastomeric material could be used. Runoff wastes could be diverted or directed to a properly prepared holding or containment pond. If the contamination hazard is only slight, or short-lived, then an unlined pit may be acceptable. If at all possible, heavy equipment should be left in the exclusion area until the cleanup operation is concluded so that heavy equipment decontamination will be required only once.

As with the PDS and the EDS for small pieces of equipment, the exact nature of the EDS for heavy equipment will be dictated by the degree and nature of the contamination and whether or not this information is known. Minimum decontamination (e.g., as with equipment contaminated with acidic residue) might include rinsing off the equipment with a neutralizing solution followed by a clear water rinse. Maximum decontamination might include partial disassembly of the equipment so that complete decontamination is possible. Facilities for decontamination could include lined pits or diked areas for the application of water, steam, detergents, complexing agents, organic solvents, acids, and caustics. Areas for wet or dry sandblasting and vacuuming may be required in extreme cases.

DECONTAMINATION EQUIPMENT AND SOLUTIONS

Ideally, the equipment used for effective and complete decontamination should be inexpensive and easily obtainable. This is also true for the various decontamination solutions. Most of the decontamination equipment listed in this section may be obtained at department, hardware, and pool supply stores at relatively small cost. Several of the items should be available from local fire stations (e.g., pumps and hoses).

Decontamination Equipment

The following list of equipment is sufficient to outfit the PDS shown in Figure C-1:

1. Plastic sheeting or tarpaulins
2. Plastic bags, assorted sizes
3. Scrub brushes, assorted sizes
4. 10-gallon plastic pails
5. 32-gallon plastic trash containers
6. Plastic wading pools or large plastic tubs
7. Sponges, assorted sizes
8. Mixing spatulas
9. First-aid kit
10. Field shower
11. Soap, brushes, and toweling for shower
12. Benches
13. Pumps
14. Hoses

Less vigorous decontamination procedures would require a reduced list of equipment. However, a well-equipped response team will have all of these items available for all eventualities. The type of equipment needing decontamination, its size and weight, and the degree and type of contamination determine the decontamination equipment required. The following is a list of equipment sufficient to outfit the EDS (shown in Figure C-2) for decontaminating small hand-held equipment:

1. Plastic sheeting or ground cloth
2. Plastic bags, assorted sizes
3. Brushes, assorted
4. 10-gallon plastic pails
5. Large plastic tubs

The following list of equipment would be required for decontamination of large earth-moving equipment that is contaminated.

1. Capability for foamed-in-place containment dikes, dams, or ponds
2. Heavy-duty liner material (elastomeric)
3. 55-gallon mixing drums
4. Pumps
5. Spray equipment (including hoses and a variety of spray nozzles)
6. Sponges, assorted sizes
7. Brushes, long- and short-handled, assorted sizes
8. Plastic bags, sheeting, tape
9. 32-gallon plastic trash containers
10. Capability for wet and dry sandblasting

An extremely useful device for applying high-pressure sprays is the Army's Portawasher. This device is built on a tandem axle trailer for portability and has a 4-gpm, 1200-psi spray capability. Additionally, the Portawasher can vacuum up and store 300 gallons of wastewater and solids.

The spray, sandblasting, and foamed-in-place containment equipment can be eliminated if the contamination is of a less serious nature.

Decontamination Solutions

Decontaminating solutions should be specifically formulated to (1) react with the contaminating compounds to produce less harmful or harmless reaction products, (2) dissolve the contaminants and thereby remove them from the subject for subsequent disposal, (3) neutralize the effects of the contaminant, or (4) any combination of the above. Even with gross contamination on clothing, equipment, etc., the use of a decontaminating solution to react with or neutralize the contaminating substance must not generate excessive heat which could cause personnel injury or damage of equipment.

The decontaminating solution should be compatible with the items being decontaminated. When the contaminant is unknown or known to be a mixture of hazardous chemicals, the decontaminating solution should be effective against a number of chemicals. Oftentimes more than one decontaminating solution should be used to assure complete decontamination. Two such decontamination solutions are:

1. An aqueous solution containing 5% sodium carbonate (Na_2CO+3) and 5% trisodium phosphate (Na_3PO_4). Mix 4 pounds of commercial grade Na_2CO_3 plus 4 pounds of commercial grade Na_3PO_4 with 10 gallons of water. These chemicals are available at most hardware stores.